THE MAP AND COMPASS . .

A PRACTICAL MODERN GUIDE TO MAP READING AND THE DAY AND NIGHT USE OF MODERN COMPASSES

BY

Captain J. Noel

Explorer and Traveller; Honourist R. Geographical Society; Formerly Instructor in Topography at Army H.Q. Officers' Training Schools.

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Explorer and Traveller and Member of the Pioneer Mt. Everest Expeditions

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Contents.

MAP READING

THE COMPASS

Points of Advantage of this Manual

1. It is written with the author's extensive *practical* experience in teaching map reading and compass work.

2. All the problems and little perplexities of map reading are clearly and concisely explained. They are made to become straightforward and simple.

3. The need to work out formulae and do calculations and arithmetic in the open country in practical map reading is eliminated by the author's provision of "ready-reckoner" tables of figures that give the *direct and immediate* answer to every problem and formula. This is a very special and unusual advantage of this book.

Further—a series of ready-calculated reference tables give the direct answer to all map reading problems in calculating—

Heights of obstructions in the line of sight.
Vertical intervals—Horizontal equivalents.
Angles of sight and slope. Gradients.

4. Conversion tables cover every conversion usually needed from British to metric measures and *vice versa*.

5. The manual is pocket size and is easily carried at hand for reference in map reading out of doors.

6. Modern compasses are fully described with their use by day and by night—together with simple astronomy and night guidance by stars.

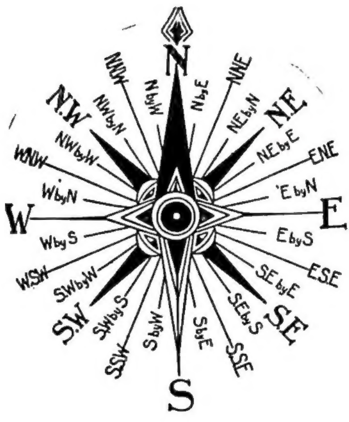
PROFUSELY ILLUSTRATED.

Over fifty illustrations and diagrams

and

Ten ready-calculated tables of figures for map reading.

Points of the Compass



CHAPTER 1

On Map Reading

Proficiency in map reading is gained only by practice after the technical matter is once mastered. With more and more practice one becomes more and more able quickly and easily to visualise the appearance of the ground from the map and to interpret details of information that an unpractised eye misses. The following headings have been compiled as an attempt to define proficiency. They also form a useful guide to a sequence in the study of map reading by laying down definite lines to follow.

If each chapter in this little manual is studied and mastered one could say at the end that one was proficient in map reading.

DEFINITION OF SKILL IN MAP READING

1. When by a first examination or swift bird's eye view over a map the eye is sufficiently practised to visualise instantly the ground in relief—to visualise the general lie of the land, the relative grouping of high ground and low ground, the general slope of the land, the direction of flow of rivers and the general line of the watersheds.

2. When by a more minute examination of the map you can

(*a*) Visualise the minor features—define the nature of slopes, whether uniform, concave or convex; get a fairly accurate idea of the gradients; be able to distinguish small features as spurs, knolls, re-entrants, under features, hollows and dips in the ground, etc.

(*b*) Be able to determine accurately the mutual visibility of points.

(*c*) Read gradients accurately and calculate angles of slopes and angles of sight.

(*d*) Calculate the heights of obstructions in the line of sight from one point to another or how high a line of sight may pass over objects on the ground.

Proficiency in visualising ground from a map comes by practice and the constant handling of maps in conjunction with studying ground. Eye for country is gained in this way and also sense of direction which is at all times and to all people a most useful quality to develop.

Map reading can be practised in two excellent ways.

First.—Go out to a commanding piece of ground with a map of the district. Study the map for 10 minutes, forming in your mind a clear idea of what the ground should look like from the map. Then look at the ground and see if your idea is correct. Note the general lie of the land, the general slope of the ground, the highest ground and the lowest. As to the minor features, notice any you have omitted. See if you have visualised correctly the shape of the slopes, uniform, convex or concave, etc.

Second.—From another position study the ground first and form an idea of what the map should appear like. Then compare notes with the map and see if your idea of the manner in which contours should represent that particular ground is correct. In studying ground in conjunction with a map set the map first and then look at the scale to get an idea of distances. Note the method of representing hill features. If contours, note the contour interval, if spot levels and shading note the height of important objects by their spot levels. It may help to colour in rivers by a blue pencil and sometimes define watersheds by another coloured line.

SETTING A MAP

A map is "set" to the ground when it is turned into such a position that directions between objects on the map correspond and are parallel to their actual directions on the ground.

The methods of setting a map are:—

(i) *By compass.*—Place the compass opened over the magnetic North and South line of the map. Turn the map until the N and S of the compass is in line with the magnetic N and S line of the map. (Fig. 1.)

(ii) *By objects on the ground.*—When you know your position on the map and can also identify the position of some other object on the ground, turn the map so that the line on your map from your position to the other object points exactly to that other object on the ground. To set the map accurately get the alignment by sighting along pins. (Fig. 2.)

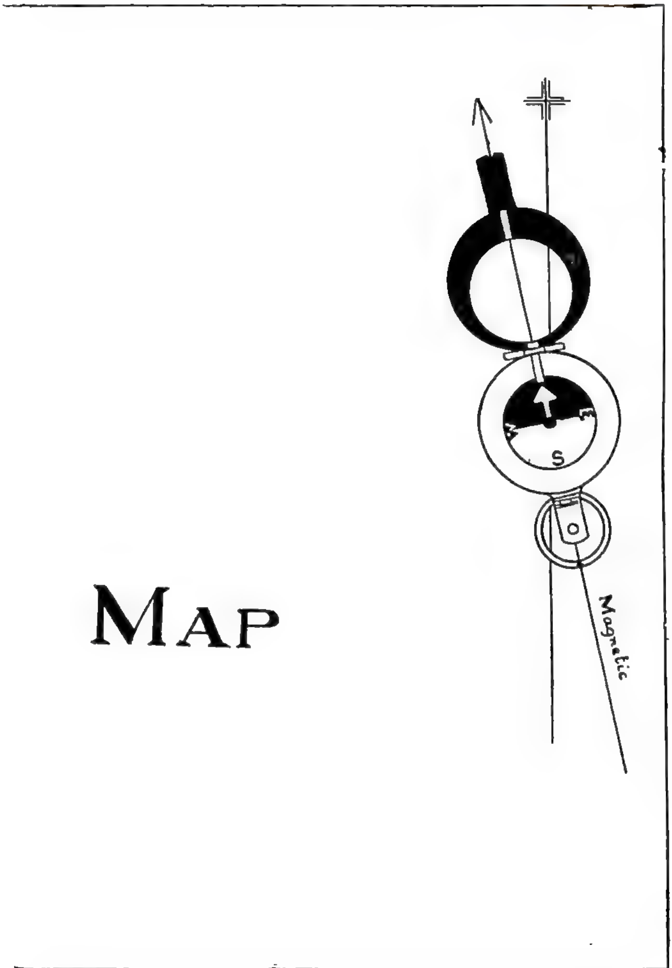


Fig. 1.

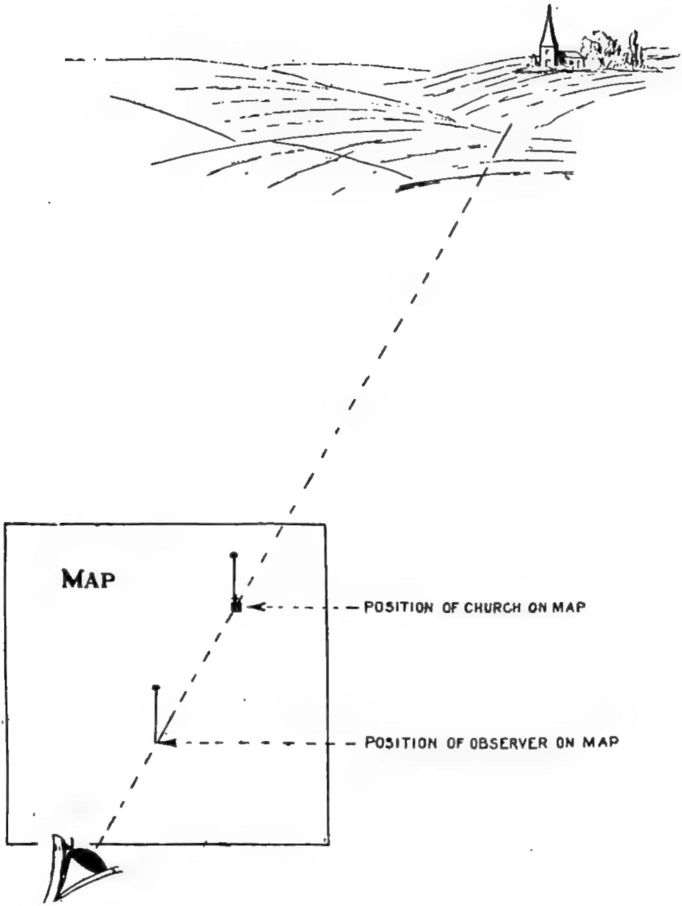


FIG. 2.

When you do not know your own position correctly on the map place yourself in line with any two objects which you can see on the ground and identify on the map. Turn the map so that the line between these two objects points directly to the two objects on the ground. If standing on a road the map can be set roughly by turning it so that the road on the map is brought parallel to the road on the ground.

The only accurate method of setting a map when you do not know exactly your position, is by the compass. Make it a rule to use the compass on all occasions.

CHAPTER 2

Map Referencing

An important requirement in map reading is to locate and describe accurately the position of a point on a map and to do this by a method that is systematised and therefore universally understood while being also simple, clear and foolproof. This is termed Map Referencing.

For this purpose the modern grid system was introduced in 1919 under the title of the "'British System." Then in 1928 the "Modified British System" as an improved modification was introduced; and this is the present day system in use.

This system divides the country mapped into squares of 500 kilometre sides, and each square is given a letter from A on to Z (but omitting the letter I).

In larger scale series of maps (¼-inch and over) these 500 km. squares are subdivided into 25 squares of 100 km. sides, and again each is given a letter A to Z, printed in the centre of the square.

In giving map references, the letters of the 100 km. square are written in capitals and are preceded by the letter of the 500 km. square, in which they lie, in small type. Thus, aK, i.e. a would indicate the 500 km. square and K the 100 km. square.

The sides of the 100 km. squares are printed in thick lines.

In still larger scale maps (1-inch and bigger) the 100 km. squares are subdivided into one hundred squares of 10 km. sides.

The left hand bottom (S.W.) corner is always taken as the zero point from which references to a position within the square are measured.

The first measurement to be made (and the first to be written down) is the distance of the point east of the S.W. corner of the square and so named "Easting." This is followed by the measurement north from the same corner and named "Northing."

Thus a reference might be written for example—aK 2543. (N.B. The method of measuring the easting and northing is described below.)

In larger scale maps (with 10 km. squares) a three figure reference is given, i.e. 653284. The first two figures (i.e. 65)

being the distance eastwards of the grid line itself and the third figure (i.e. 3) being the easting measurement of the point within the square. Similarly with the northing measurement.

In these very large scale maps the letters of the 500 km. and the 100 km. squares are usually omitted for simplicity when the referencing is obvious without them and only the six-figure reference is given.

The method of arriving at the easting and northing measurements is:—

(i) By a visual estimation in relation to an imaginary subdivision of the sides of the square into 10 equal divisions.

(ii) By an accurate measurement made by the aid of a "Romer." This is a simple rectangular card or piece of paper carrying on its top and right hand edges a series of ten graduations reading outwards from the top right hand corner, which is marked with an arrow.

The arrow corner is placed on the point on the map (with the romer held square and parallel to the map grid lines) and the easting and northing measurements read off.

Ready made romers are obtainable printed on card or celluloid to suit different scales of maps, and they carry printed instructions for their use.

REFERENCING BY LATITUDE AND LONGITUDE

Referencing to the position of any place on the surface of the earth may be done very conveniently in terms of latitude and longitude. This method is applicable mainly to the relatively smaller scale maps—say 1: 100,000 down to atlas maps. The gazeteers of atlases always refer to all place-names by latitude and longitude.

It is a great pity that this simple, clear and precise method is not used more in daily life when people have occasion to refer to specific lesser known place names either in their own or in foreign countries. A haphazard reference is most irritating and wasteful of time to others who wish to locate on a map a place that happens to be unknown to them. Without a latitude and longitude reference they are driven to hunt all over the map to find the place.

It must be remembered that, while most countries of the world use the meridian of Greenwich for their zero meridian of longitude, some countries select their own, based usually on their capital city. In such cases the necessary conversion to the Greenwich meridian can easily be made.

Every map always shows the parallels of latitude on both the right hand and left hand margins, and the meridians of

longitude on the top and bottom margins. A pair of dividers is useful for measuring off accurately.

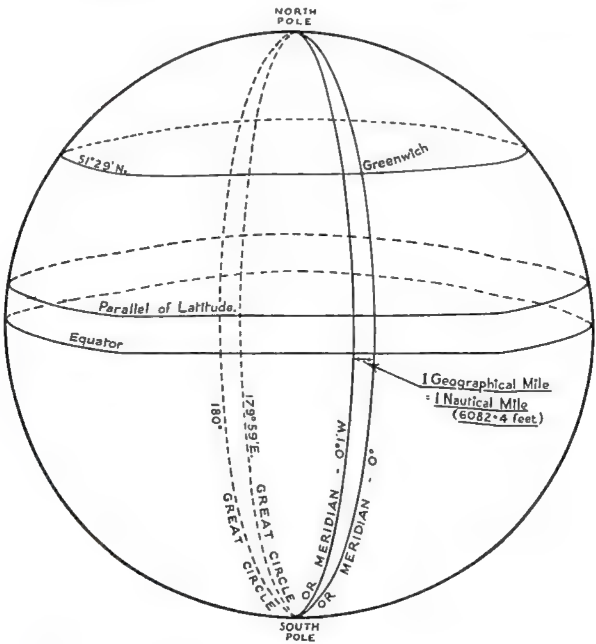
References are written with the latitude first, followed by the longitude, thus:—

Lough Nafooey 53° 34′ N., 9° 33′ W.

N.B. 1. A degree of latitude or of longitude is subdivided into 60 minutes, and minutes into 60 seconds.

Usually it is sufficient to give a reference to the minutes only.

2. The distance subtended along the earth's equator of one minute of longitude is one Geographical Mile—6080 feet. (A Statute Mile equals 5280 feet). The Nautical Mile is equivalent to the Geographical Mile.



PARALLELS OF LATITUDE AND MERIDIANS OF LONGITUDE.

CHAPTER 3

Scales

The scale of a map is the proportion of distances between objects on the map to the actual distances between them on the ground. This proportion may be expressed either by the relation of "so many inches to the mile" or by a representative fraction such as $\frac{1}{10,000}$ written sometimes 1:10,000. The Representative Fraction, taking the example of the R.F $\frac{1}{10,000}$. means that a distance of 1 inch between 2 points on the map represents an actual distance between them of 10,000 inches on the ground. This would be the same with any other unit besides inches. One unit on the map represents 10,000 units on the ground.

To find how many inches to the mile any R.F. represents divide 63,360 by the denominator of the R.F.

$$\text{Inches to the mile} = \frac{63,360}{\text{Denominator R.F.}}.$$

63,360 is the number of inches there are in one mile.

Take the R.F. $\frac{1}{10,000}$. This in inches to the mile will then be $\frac{63,360}{10,000} = 6$ inches to the mile approximately.

On maps of small scale it may be more convenient to find how many "miles to the inch" the R.F. represents instead of "inches to the mile."

$$\text{Miles to the inch} = \frac{\text{Denominator R.F.}}{63,360}.$$

Take the R.F. $\frac{1}{250,000}$.

$$\text{Miles to the inch} = \frac{250,000}{63,360} = 4 \text{ approximately.}$$

4 miles to the inch nearly.

Scales are usually about 6 inches long. They are found at the foot of the map. The scale comprises always primary and secondary divisions. Thus a scale of 4 inches to the mile would show primary divisions of miles and one primary

on the left of the scale divided into secondaries, say furlongs or 100 yards. The primaries and secondaries start at 0 and read outwards from one another.

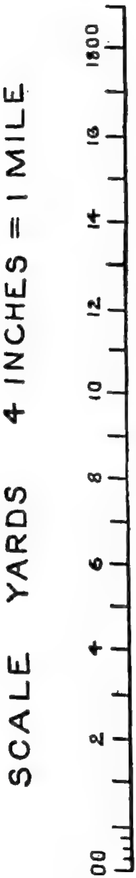


FIG. 3.

The method of constructing scales will be understood from the following examples:—

Example 1.—Construct a scale of 4 inches to 1 mile to show yards.

We have seen that scales are always about 6 inches long, so the first problem in making a scale is to determine what would be a convenient number of primary units that would be represented by a length of scale about 6 inches. In this case 1 mile or 1,760 yards is represented by 4 inches, so 2,000 yards, whioh is a convenient round number, would be suitable to show in the scale to make it about 6 inches long.

Having determined the number of primaries to be shown in our scale the next step is to calculate the exact length of the scale to show that number of primaries. Take the above case of a scale 4 inches to 1 mile. We have decided to show 2,000 yards on the scale. What length of line would 2,000 yards be represented by?

One mile (1,760 yards) is represented by 4 inches.

Therefore, 2,000 yards will be represented by $\frac{2{,}000 \times 4}{1{,}760} = 4{\cdot}54$ inches.

We now draw a line 4·54 inches long with the aid of a diagonal scale and divide it into 20 parts or primaries of 100 yards. The left-hand primary could be divided into 4 secondaries to show 25 yards.

Example 2.—Constructing a scale from a R.F.

Construct a scale of miles R.F. $\frac{1}{250{,}000}$.

The first problem is to find how many miles a scale length of about 6 inches would show.

1 inch represents 250,000 inches. Therefore 6 inches will represent 250,000 × 6 inches, or

$$\frac{250{,}000 \times 6}{63{,}360} = 23{\cdot}7 \text{ miles.}$$

Thus 25 miles would be convenient number of miles to show on the scale to get the scale about 6 inches long.

23·7 miles are represented by 6 inches.

25 miles will be represented by $\frac{25 \times 6}{23{\cdot}7} = 6{\cdot}34$ inches

6·34 inches will be the length of the scale. This when divided into five parts will show primaries of 5 miles and the left-hand primary can be divided into five parts to show secondaries of single miles.

If the problem had been to make a scale of kilometres, or any other unit, instead of miles, the same method would be followed thus:—

1 cm. represents 250,000 centimetres.

15 cm. (about 6 inches) represents 250,000 × 15 cm.

$$= \frac{250{,}000 \times 15}{1{,}000 \times 100} \text{ kilometres} = 37{\cdot}5 \text{ kilometres.}$$

40 kilometres would then be a convenient number to show on the scale.

Length of scale would be

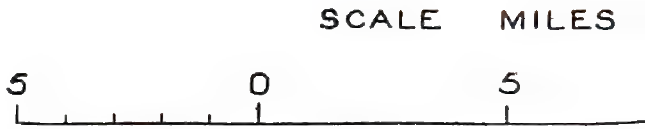
$$\frac{15 \times 37{\cdot}5}{40} = 14{\cdot}06 \text{ cm.}$$

COMPARATIVE SCALES

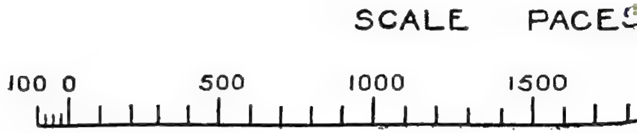
On many occasions the utility of a map can be increased by adding to it a comparative scale for some special purpose. One such purpose might be for night marching in which distances were to be measured direct in paces according to the normal pace of the individual or again in time, that is the scale would measure distances not in yards or miles but in the number of minutes or hours it would take to walk those distances.

Example.—Make a scale of paces for a map R.F. 1: 20,000. The individual taking 2,000 paces to the mile.

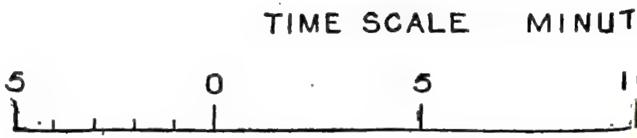
The scale in inches to the mile $= \frac{63{,}360}{20{,}000} = 3{\cdot}16$ inches.



FIG



FIG



FIG

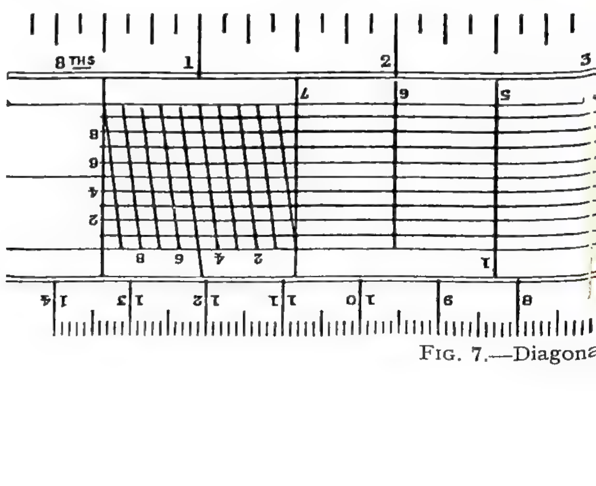
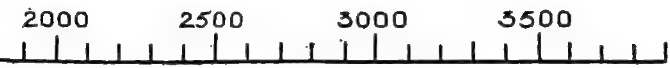


FIG. 7.—Diagona

R F 1:250,000

4.

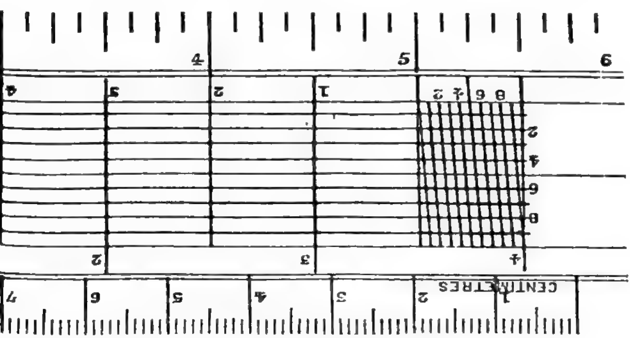
R F 1:20,000



5.

ES R F 1:10,000

6.



l Scale of Inches.

To get our scale about 6 inches long we could show 2 miles or 4,000 paces as a suitable round number.

Thus mark off a line 6·32 inches long which will be the length of scale to show 4,000 paces. This can be divided up conveniently into hundreds of paces as primaries and secondaries of 25 paces.

Example 2.—Make a time scale for night marching for a map of R.F. 1: 10,000 for a man who walks 2 miles per hour.

$$\text{R.F. } 1:10{,}000 = \frac{63{,}360}{10{,}000} = 6.33 \text{ inches to the mile.}$$

To get the scale about 6 inches long it could conveniently be made to show one mile representing half an hour or 30 minutes in time.

Mark off a line 6·33 inches long and divide this into six to show primaries of five minutes and divide the left-hand division into secondaries of single minutes.

To construct a scale for a map which has no scale on it.

Measure the distance carefully in inches on a diagonal scale between any two points on the map. Measure the actual distance between these same two points on the ground by range-finding instruments or by pacing the distance if no instruments are available.

The R.F. can then be found because

$$\text{This is } \frac{\text{Distance on map in inches}}{\text{Distance on ground in inches}}.$$

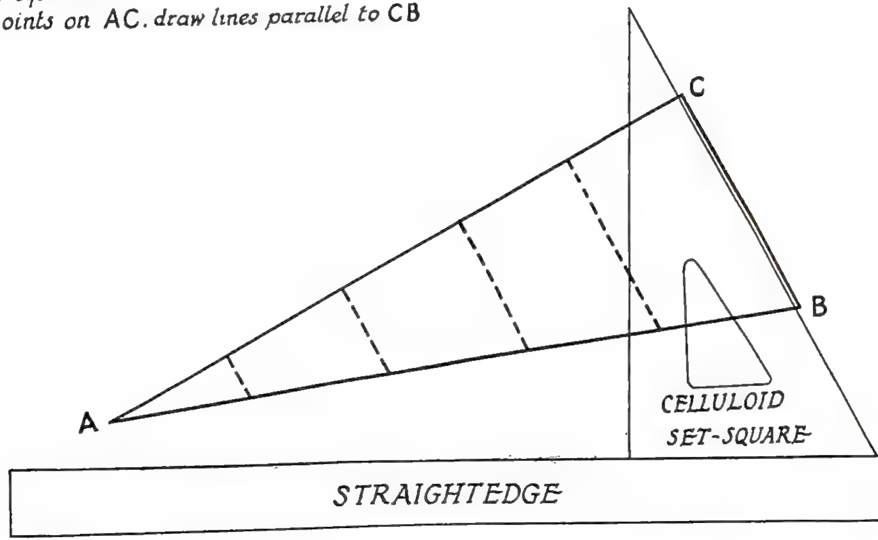
To use a Practractor to draw any scale.—The following method by W. M. Dickinson, B.A., is very practical and useful. It enables one to draw any scale from any other one. In the ordinary way of constructing scales diagonal and Marquois scales are used to measure the length of the scale and to divide it up into equal parts or primaries and secondaries. But this method obviates the use of these instruments and by its means any scale can be drawn straight from any other one that may be available on a protractor or ruler.

Supposing we have a 2 inch to 1 mile scale available. It is obvious that—

100	yards on the	2 inch scale	=200	yards on the	1 inch	scale
300	,,	,,	=200	,,	3 inch	,,
400	,,	,,	=200	,,	4 inch	,,

HOW TO DIVIDE A LINE 'A B' INTO A GIVEN NO. OF EQUAL PARTS

Along any line AC mark off required no. of equal divisions. Join CB, and from all points on AC. draw lines parallel to CB



From this we can deduce that—

X00 yards on the 2 inch scale = 200 yards on the X inch scale.

Example.—Draw a scale of yards R.F. $\frac{1}{5,000}$.

$$\text{R.F. } \frac{1}{5,000} = \frac{63,360}{5,000} = 12{\cdot}67 \text{ inches to the mile.}$$

12·67 yards on the 2 inch scale = 200 yards on the 12·67 inch scale.

From the 2 inch scale we measure off the distance 12·67 yards and this length gives us the length of 200 yards on the required scale of $\frac{1}{5,000}$. From this the rest of the scale can easily be completed.

If the units of the required scale are not in yards, say the required scale is one of metres or kilometres, then the following rule applies:—

(X00 × Unit in terms of yards) yards on the 2 inch scale = 200 units of the required scale.

Example.—Draw a scale of metres $\frac{1}{25,000}$.

$$\text{R.F. } \frac{1}{25,000} = \frac{63,360}{25,000} = 2{\cdot}53 \text{ inches to 1 mile.}$$

253 yards on the 2 inch scale = 200 yards on the 2·53 inch scale.

The unit, metres, must be converted into yards.

Metres in terms of yards are given by $\frac{39}{36}$.

Therefore the equation becomes $(253 \times \frac{39}{36})$ yards on the 2 inch scale = 200 metres on the required scale of.......... $\frac{1}{25,000}$.

This gives us the length of 200 metres on the required scale of $\frac{1}{25,000}$; and so the rest of the scale can be completed.

CHAPTER 4

Foreign Units of Measure and Conversion Tables

The metric system as under is used in:—Argentine, Austria, Belgium, Bolivia, Brazil, Bulgaria, Columbia, Costa Rica, Ecuador, France, Germany, Greece, Holland, Italy, Norway, Portugal, Roumania, Servia, Spain, Sweden, Switzerland, Turkey and Venezuela.

Millimetre	=	·039 inches.	
Centimetre	=	·394 ,,	
Decimetre	=	3·937 ,,	
Metre	=	39·37 ,,	(1·094 yards.)
Kilometre (1,000 metres	=	1,093·633 yards.	

(8 kilometres = 5 miles approx.)

U.S.A.

As in England.

RUSSIA

Sajen	=	7 feet
Verst (500 Sajen) ..	=	1,166·6 yards

EGYPT

Kadam	=	1 foot
Diraa or Pih	=	28·83 inches
Kassaba	=	11·6 feet

CHINA

Ts'un	=	1·41 inches
Ch'ih (10 Ts'un) ..	=	14·1 inches
Chang (10 Ch'ih) ..	=	141 inches
Li	=	$\frac{1}{3}$ mile (approx.)

JAPAN

Ken (6 shaku)	=	1·988 yards
Cho (60 ken)	=	119·3 yards
Ri (36 Cho)	=	2·44 miles

INDIA

Ungul	=	.75 inches
Hath	=	18 inches
Gaz	=	1 yard
Kos	=	2,000 yards

TABLE FOR CONVERTING FEET TO METRES

(1 foot = 0·3048 metres)

Feet	0	1	2	3	4	5	6	7	8	9
0 ..	—	0·30	0·61	0·91	1·22	1·52	1·83	2·13	2·44	2·74
10 ..	3·05	3·35	3·66	3·96	4·27	4·57	4·88	5·18	5·49	5·79
20 ..	6·10	6·40	6·7	7·01	7·31	7·62	7·92	8·23	8·53	8·84
30 ..	9·14	9·45	9·75	10·06	10·36	10·67	10·97	11·28	11·58	11·89
40 ..	12·19	12·50	12·8	13·11	13·41	13·72	14·02	14·32	14·63	14·93
50 ..	15·24	15·54	15·85	16·15	16·46	16·76	17·07	17·37	17·68	17·98
60 ..	18·29	18·59	18·90	19·20	19·51	19·81	20·12	20·42	20·73	21·03
70 ..	21·33	21·64	21·94	22·25	22·55	22·86	23·16	23·47	23·77	24·08
80 ..	24·38	24·69	24·99	25·3	25·6	25·9	26·21	26·52	26·82	27·13
90 ..	27·43	27·74	28·04	28·35	28·65	28·95	29·26	29·56	29·87	30·17
100 ..	30·48	—	—	—	—	—	—	—	—	—

TABLE FOR CONVERTING METRES TO FEET

(1 metre = 3·2809 feet)

Metres	0	1	2	3	4	5	6	7	8	9
0 ..	—	3·28	6·56	9·84	13·12	16·40	19·68	22·97	26·25	29·53
10 ..	32·81	36·09	39·37	42·65	45·93	49·21	52·49	55·77	59·06	62·34
20 ..	65·62	68·90	72·18	75·46	78·74	82·02	85·30	88·58	91·86	95·15
30 ..	98·43	101·71	104·99	108·27	111·55	114·83	118·11	121·39	124·67	127·95
40 ..	131·24	134·52	137·80	141·08	144·36	147·64	150·92	154·20	157·48	160·76
50 ..	164·04	167·33	170·61	173·89	177·17	180·45	183·73	187·01	190·29	193·57
60 ..	196·85	200·13	203·42	206·70	209·98	213·26	216·54	219·82	223·101	226·38
70 ..	229·66	232·94	236·22	239·51	242·79	246·07	249·35	252·63	255·91	259·19
80 ..	262·47	265·75	269·03	272·31	275·59	278·88	282·16	285·44	288·72	292·00
90 ..	295·28	298·56	301·84	305·12	308·40	311·68	314·97	318·25	321·53	324·81
100 ..	328·09	—	—	—	—	—	—	—	—	—

TABLE FOR CONVERTING YARDS TO METRES
(1 yard = 0·914383 metres)

Yards	0	1	2	3	4	5	6	7	8	9
—	—	0·91	1·83	2·74	3·66	4·57	5·48	6·40	7·31	8·23
10 ..	9·14	10·06	10·97	11·89	12·80	13·72	14·63	15·54	16·46	17·37
20 ..	18·29	19·20	20·12	21·03	21·94	22·86	23·77	24·69	25·60	26·52
30 ..	27·43	28·35	29·26	30·17	31·09	32·00	32·92	33·83	34·75	35·66
40 ..	36·57	37·49	38·40	39·32	40·23	41·15	42·06	42·97	43·89	44·80
50 ..	45·72	46·63	47·55	48·46	49·38	50·29	51·20	52·12	53·03	53·95
60 ..	54·86	55·78	56·69	57·61	58·52	59·43	60·35	61·26	62·18	63·09
70 ..	64·01	64·92	65·84	66·75	67·66	68·58	69·49	70·41	71·32	72·24
80 ..	73·15	74·06	74·98	75·89	76·80	77·72	78·64	79·55	80·47	81·38
90 ..	82·29	83·21	84·12	85·04	85·95	86·87	87·78	88·69	89·61	90·52
100 ..	91·44	—	—	—	—	—	—	—	—	—

Table for Converting Metres to Yards

(1 metre = 1·093633 yards)

Metres	0	1	2	3	4	5	6	7	8	9
— ..	—	1·09	2·19	3·28	4·37	5·47	6·56	7·65	8·75	9·84
10 ..	10·94	12·03	13·12	14·22	15·31	16·40	17·50	18·59	19·68	20·78
20 ..	21·87	22·97	24·06	25·15	26·25	27·34	28·43	29·53	30·62	31·71
30 ..	32·81	33·90	34·10	36·09	37·18	38·28	39·37	40·46	41·56	42·65
40 ..	43·74	44·84	45·93	47·03	48·12	49·21	50·31	51·40	52·49	53·59
50 ..	54·68	55·77	56·87	57·96	59·06	60·15	61·24	62·34	63·43	64·52
60 ..	65·62	66·71	67·80	68·90	69·99	71·09	72·18	73·27	74·37	75·46
70 ..	76·55	77·65	78·74	79·83	80·93	82·02	83·12	84·21	85·30	86·40
80 ..	87·49	88·58	89·68	90·77	91·86	92·96	94·05	95·15	96·24	97·33
90 ..	98·43	99·52	100·61	101·71	102·80	103·89	104·99	106·08	107·18	108·27
100 ..	109·36	—	—	—	—	—	—	—	—	—

TABLE FOR CONVERTING STATUTE MILES TO KILOMETRES

(1 mile = 1·60931 kilometres)

Miles	0	1	2	3	4	5	6	7	8	9
—	—	1·61	3·22	4·83	6·44	8·05	9·65	11·26	12·87	14·48
10 ..	16·09	17·70	19·31	20·92	22·53	24·14	25·75	27·35	28·97	30·58
20 ..	32·18	33·80	35·40	37·01	38·62	40·23	41·84	43·45	45·06	46·67
30 ..	48·28	49·89	51·50	53·11	54·72	56·33	57·93	59·54	60·15	62·76
40 ..	64·37	65·98	67·59	69·20	70·81	72·42	74·03	75·64	77·25	78·86
50 ..	80·47	82·07	83·68	85·29	86·90	88·51	90·12	91·73	93·34	94·95
60 ..	96·56	98·18	99·77	101·39	102·97	104·60	106·21	107·84	109·43	111·04
70 ..	112·65	114·26	115·87	117·48	119·09	120·70	122·31	123·92	125·53	127·14
80 ..	128·74	130·35	131·96	133·57	135·18	136·79	138·40	140·01	141·62	143·23
90 ..	144·84	146·45	148·06	149·67	151·28	152·88	154·49	156·13	157·71	159·32
100 ..	160·93	—	—	—	—	—	—	—	—	—

TABLE FOR CONVERTING KILOMETRES TO STATUTE MILES

(1 kilometre = ·62138 miles)

Kilom.	0	1	2	3	4	5	6	7	8	9
—	—	0·62	1·24	1·86	2·48	3·11	3·73	4·35	4·97	5·59
10 ..	6·21	6·83	7·46	8·08	8·70	9·32	9·94	10·56	11·18	11·80
20 ..	12·43	13·05	13·67	14·29	14·91	15·53	16·15	16·77	17·40	18·02
30 ..	18·64	19·26	19·88	20·50	21·13	21·75	22·37	22·99	23·61	24·23
40 ..	24·85	25·47	26·10	26·72	27·34	27·96	28·58	29·20	29·83	30·45
50 ..	31·07	31·69	32·31	32·93	33·55	34·18	34·80	35·42	36·04	36·66
60 ..	37·28	37·90	38·52	39·15	39·77	40·39	41·01	41·63	42·25	42·87
70 ..	43·50	44·12	44·74	45·36	45·98	46·60	47·25	47·85	48·47	49·09
80 ..	49·71	50·33	50·95	51·57	52·20	52·81	53·44	54·06	54·68	55·30
90 ..	55·92	56·54	57·17	57·79	58·41	59·03	59·65	60·27	60·89	61·52
100 ..	62·14	62·76	63·38	64·00	64·62	65·24	65·87	66·49	67·11	67·73

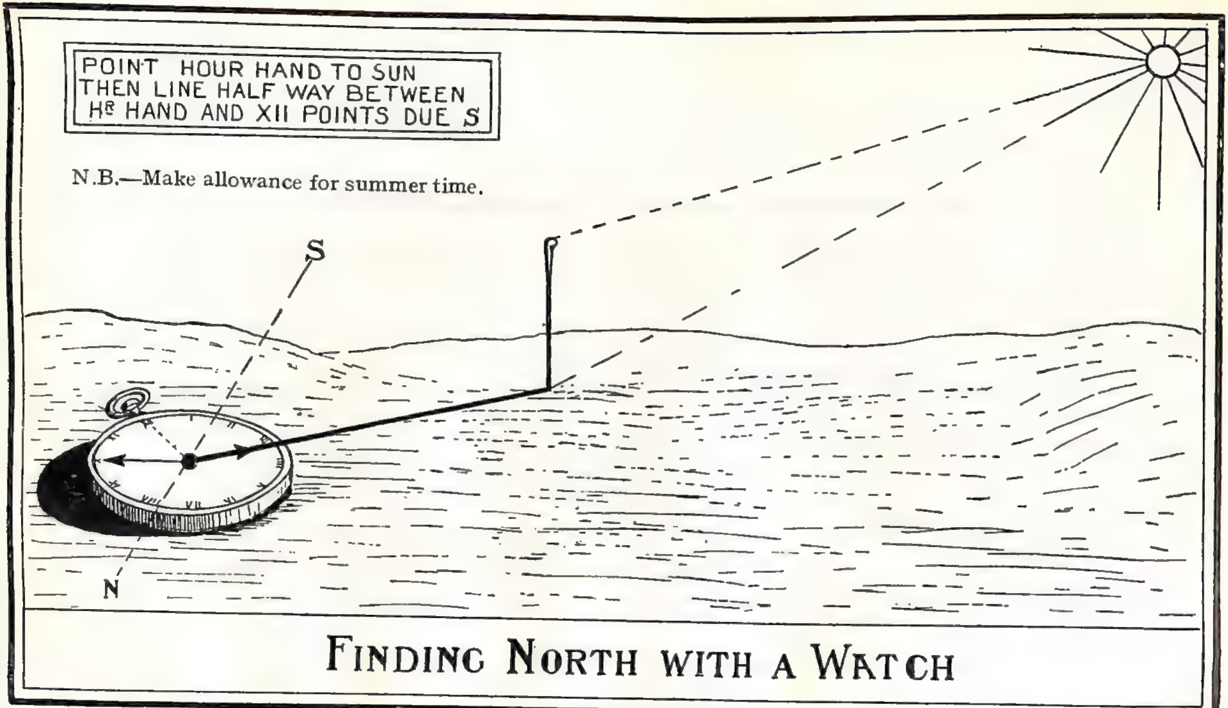

POINT HOUR HAND TO SUN
THEN LINE HALF WAY BETWEEN
Hr HAND AND XII POINTS DUE S
N.B.—Make allowance for summer time.
S
N
FINDING NORTH WITH A WATCH

FIG. 8.

CHAPTER 5

The Representation of Relief of Ground in Maps

The difficult problem of the map maker is to indicate the relief of ground on the flat surface of the map. To do this several different methods can be employed. No one method can be standardised and adopted for all maps because different maps are made to serve different purposes. Some may not require to show relief vividly, and the map maker may be content with using contours; but in other maps the scale may perhaps be too small to render contours useful, and then some other method has to be employed.

The methods now employed generally come under two headings.

1. The Mathematical.

(*a*) Contours.
(*c*) Form Lines.
(*b*) The Layer system of colouring.

In these the aim of the map maker is to indicate with *precision* the heights of features of the ground and also the modelling and form of the surface of the land.

2. The Pictorial or Artistic.

(*a*) Hachuring.
(*b*) Brush Shading.
(*c*) Stereoscopic Colour Tinting.

In these methods the aim of the map maker is to indicate *pictorially* the modelling of the ground relief without giving a *precise mathematical* indication of heights.

These systems are combined sometimes one with another, as for instance—contours combined with hachures, the layer system combined with shading.

The requirements of a perfect system of indicating relief are that—

1. The absolute heights of all points of the ground must be shown so that those heights can be read by anyone using the map.

2. The relative heights of different features of the ground should be apparent to the eye.

3. A truthful and complete indication of the mould or modelling of the details of the surface relief should be given.

We can now study each method in turn and see its characteristics; and see in which cases each system or combination of systems is most suited to different kinds of maps.

Contours.—Contours are the most accurate way of showing relief. They afford an accurate indication of the absolute heights of features of the ground and also, if drawn at a narrow contour interval, they can convey to the eye an accurate idea of the mould and form of all the minor irregularities of the surface features. They can be used to interpret the angle of slope either by measurement and calculation, giving the exact angle in figures, or to convey a fairly close idea to the eye by inspection.

The intervals at which contours are drawn depend upon the scale of the map. Topographical maps on a scale of 1:10,000 are generally contoured at 5-metre intervals and this is very convenient for working out problems and calculations and reading surface features as in military work.

In the 1 inch ordnance survey the contours are at 100 feet intervals. This is rather wide, and it is a pity more contour lines are not put in or even form lines. The general tendency of modern map makers seems to be in increasing the contour lines and at the same time developing the layer system of colour tinting to emphasise to the eye more vividly than contours alone do, the relative heights of features in the surface relief.

Contours have their limitations. As the map scale decreases the contour interval must increase until in the small scale geographical map contours are at so wide an interval that they lose their power of defining the form of the ground. Some other method has then to be employed.

Contours, as opposed to other systems of showing relief, require a certain degree of skill in the map reader before he can interpret from them the shape of the ground and form

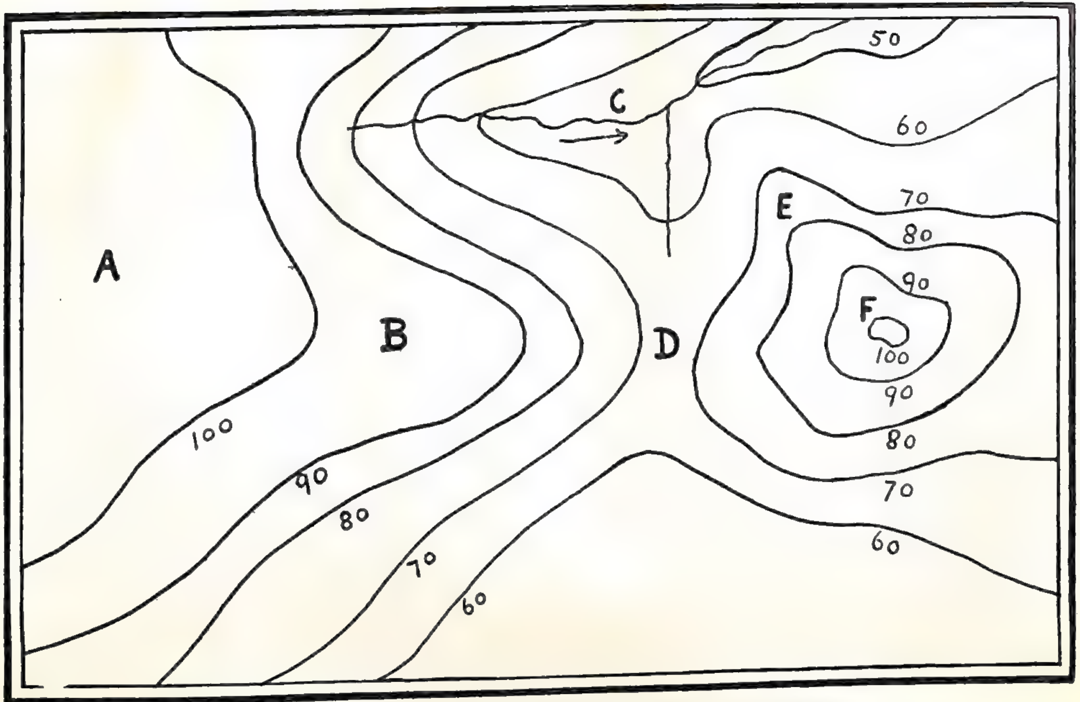


FIG. 9.—The Representation of Relief of Ground by Contours.

A.—Plateau. B.—Ridge. C.—Valley (and river). D.—Saddle. E.—Spur. F.—Hill.

a correct idea of slopes. Therefore an explanation of contours is now given for those who require such an explanation.

A contour line is a level line. Take for instance a contour marked 100 feet on a map. All the points on a map through which that contour passes are at the same height, 100 feet. Again the idea of contours can be well understood by imagining them as water levels of a rising flood which has inundated the land. As the flood rises the water level would form curved winding lines fitting into the irregularities of the hill features. If the water level were traced out on the ground for every even 100 feet the water rose, one would find the ground covered by a series of winding lines of equal level, one 100 feet above the other, when the flood receded. This is exactly what contours of a map represent.

From studying how such water levels would fit and shape themselves to hill features we can draw diagrams of how different shapes of ground appear in contours. See Figure 9. Similarly, having understood and memorised these diagrams, we can apply them in their turn to visualising ground from a map. In this way we train our eyes to "read a map."

If teaching or lecturing on map reading, a most striking way in which to explain contours and give practice in representing relief of ground by contours is to have a relief model map made with relief standing out about 3 to 4 feet. Such models are easily made over a wooden framework with wire netting over which is spread canvas and paper soaked in glue. The surface thus made is quite hard and strong and can be painted as required. A rough skeleton map is made of the model showing only spot levels of prominent features and the lines of rivers and roads, etc. The student is made to fill in his skeleton map by form lines to depict correctly the relief of the model. His efforts and results are then checked and corrected. The exercise can be made even more interesting by arranging in the construction of the model to pierce lines of small holes at one inch apart along the line of contours. These are covered over with a sheet of thin paper. The holes cannot be seen normally, but they stand out visibly if an electric light placed underneath the model is turned on.

Form Lines.—Form lines are contour lines but they are not drawn with mathematical precision. They are hand sketched by the map maker on the ground. In order that they may not be confused with contours which are surveyed and drawn with mathematical accuracy, form lines are shown as dotted or broken lines. They are an exceptionally valuable

addition to an ordinary contoured map, because they indicate the exact shape of all those minor features on the ground which may be missed by the contours at regular intervals. For instance, between two contour lines 150 and 170 feet in a certain map, there may be a projecting underfeature whose existence is not indicated by the regular contours because it is missed by both the higher and lower ones. Form lines between these contours would, however, at once indicate both the existence and the shape of the underfeature. When many form lines are sketched in, a result much approaching the effect of hachuring and shading is gained. Maps are sometimes made with form lines only without any contours. These are generally of imperfectly surveyed countries.

The Layer System.—In this system, which is widely employed now, the intervals between certain contours are tinted in colour. A graduated scale of colour ranging usually from light to dark is used to indicate an ascending scale of heights. Either the tints are all of one colour which is preferable perhaps, or the scale comprises several different colours. The contour intervals selected for colouring have to be judiciously chosen with regard to the general grouping and relative heights of the hill features, and upon this choice the relief effect obtained depends.

A disadvantage is to give an appearance of terraces which is untruthful to any shape of ground.

Brush Shading.—1. With Vertical Illumination.—Here the light is supposed to strike the ground from vertically above, so steep slopes will be depicted by dark shading, the gentler slopes by lighter shading and flat ground as white paper. This is the scale in which the surface of the ground would reflect the vertical light rays. The merit of this system of shading is that the modelling of slopes is correctly indicated and the degrees of shade can be used to interpret the relative steepness of slopes.

2. With Side Illumination.—Here the light is supposed to strike the ground from the N.W. direction or from the top left-hand part of the map. This method of shading has the merit of vividly showing the relief of the ground, but it fails to indicate the modelling of slopes because it will be seen there is no means of differentiating between the shade of the steeper and the lesser slopes. All those slopes facing the N.W. will be light and all those in the other direction will be cast in shadow.

The N.W. slope of a hill may be a steep one and the other side gentle, but the shading would tend to make it appear that the opposite was the case. For this reason maps using this system of shading frequently have contours or form lines combined with the shading in order to indicate slopes while the shading emphasises the relief.

Vertical Hachuring.—This system consists of indicating slopes by fine lines sketched down the line of steepest slope. The lines are closely packed for steep slopes and relatively wide apart for gentle slopes. In sufficiently large scale maps

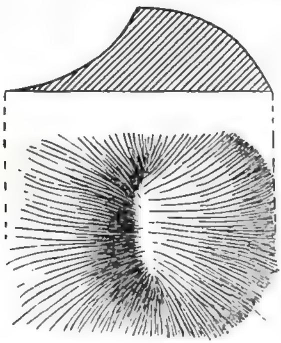


FIG. 10.—The principle of Hachuring.

the hachures may be drawn to scale so that they can be used to afford a mathematical or precise indication of the relative degree of slope.

Hachures depict the modelling of slopes well, but they fail rather in emphasising the relative heights and they fail altogether in indicating absolute altitudes.

Slopes can be interpreted from the hachures by the aid of the diagram figure (10), remembering that the line of the hachures indicates the line of steepest slope.

Hachures are often combined with shading with vertical or side illumination to show up better the general modelling of the relief and to accentuate relative heights.

Relief Effect by Colouring.—There are great possibilities in the use of colour to gain relief effect in maps. We have

seen the layer system of colouring in which certain tints represent certain heights. A visible relief effect for the eye is gained by such colour layers besides the precise indication of height they already afford.

There is another method of using colours, not aiming at any mathematical indication of heights as the layer system but aiming at conveying artistically the impression of relief. This method of stereoscopic colour tinting is most useful in some kinds of map, such as wall maps and maps for physical geography.

Colours are used in a graduated scale according to the order of their refrangibility. The spectrum of light as given by a prism ranges from red through orange to blue greens and greenish grey tints to green. Now when tints in this order are used to represent a scale of heights a very marked relief effect is gained—a stereoscopic effect is gained. In the application of this system the deepest reds are used to indicate the highest ground and greens the lowest. The eye, looking over the ground from vertically above, gets the impression of the reds being drawn up out of the map while the greens seem to recede. From the imaginary point of view above the ground this conveys a right impression because the hill tops (the deepest reds) would be the nearest while the valley bottoms and plains (or greens) would be furthest.

General.—Having seen the various methods of representing the relief of ground in maps we can conclude by noting the general occasions in which each system or combination of systems is most useful to different kinds of maps and therefore is most usually found in those classes of maps.

Maps and plans come under these headings according to their scale:—

Cadastral—large scale plans.
Topographical.
Geographical.
Atlas maps.

On plans generally relief is not represented at all. If it is it would be by contours.

In topographical maps R.F. 1: 5,000 to 1: 25,000 contours only are generally employed. In smaller scales to 1: 200,000 contours and hachuring combined are usually found, or hachuring and spot levels in maps not constructed in contours, like some maps of France and Germany.

Geographical maps of R.F. 1: 200,000 to 1: 1,000,000 are generally contoured as here the scale is too small to allow

hachuring to show the modelling of slopes which is its principal utility. Contours supplemented by layers of colour are sometimes found in maps of these scales.

In smaller scale geographical maps than 1: 1,000,000 contours need to be at such wide intervals that they become almost useless to show the shape of hill features. Furthermore in these small scales it is more important to indicate broadly the relative grouping of hills and mountains in relation to flat country than to emphasise the minute intricacies of the shape of hills for which contours are intended, so some other method such as the layer system, shading or shading combined with colour is used.

In atlas maps fine forms of shading only can be used.

In maps of imperfectly surveyed countries relief is generally expressed by form lines and spot levels on topographical scales, and by shading with inclined illumination in geographical scales, viz., parts of the Himalayas on the Indian survey maps.

CHAPTER 6

Visualising Minor Features of Relief from a Contoured Map

In the preceding chapter we have seen that a contour is a line of a certain level as seen from an imaginary bird's eye view from above. We will draw sketches of the different shapes of ground, to show how these appear in contours, and we can then fix these diagrams in the memory, so that, in their turn, they can be used to interpret the relief of the ground when we come to read a map. See Figure 9. These diagrams are the representation in contours of the main forms of relief of ground.

Now to visualise the relief of the minor features requires some practice and skill. The diagram (Figure 11) if studied will be a valuable help. Read always from high ground to low ground. Which ground is relatively high and which low can be seen by the heights of the contours. For the illustration high ground is shown by a continuous contour representing the top of a hill.

RULES

1. When the contour spacing is even as in Plan 1 the slope is uniform.

2. Reading from high ground to low when the contour spacing increases the ground is concave as in Plan II.

3. Reading from high ground to low again when the contour spacing decreases the ground is convex as in Plan III.

NOTE.—Uniform and concave slopes afford no dead ground and one end of the slope can be seen from the other except for any natural objects on the surface of the ground which may intervene and cause an obstruction in the line of sight. In convex slopes there is dead ground. One extremity is invisible from the other.

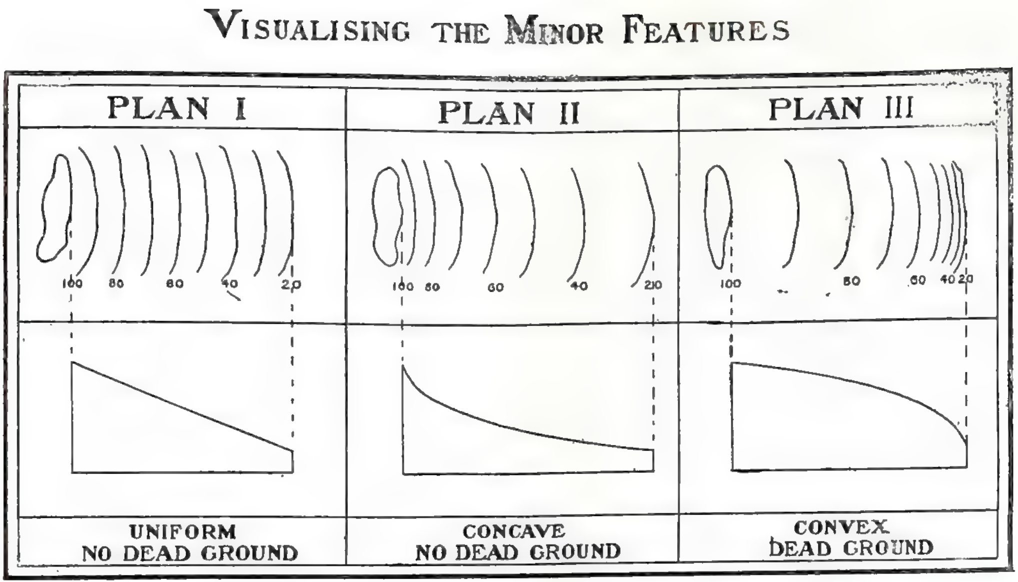

VISUALISING THE MINOR FEATURES
PLAN I
PLAN II
PLAN III
100
80
60
40
20
UNIFORM
NO DEAD GROUND
CONCAVE
NO DEAD GROUND
CONVEX
DEAD GROUND

FIG. 11.

VERTICAL SECTION

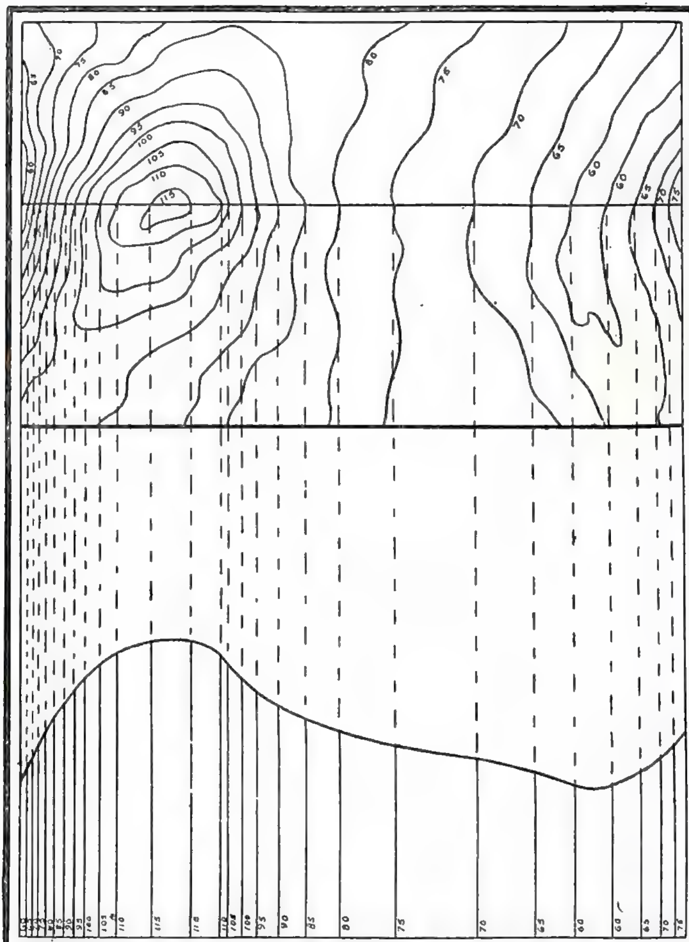


FIG. 12

CHAPTER 7

Sections

If one is not skilled in visualising the shape of the ground from the contours, or if one wishes to see exactly the relative heights and slopes of different small underfeatures, one can make with advantage a section of the ground from the map. Sections have other uses as well, namely, to convey an idea of the shape of the ground to somebody else who is unable to read a map and also to solve problems of mutual visibility of points and heights of obstructions in the line of sight from one point to another.

The most convenient method of constructing a section is to use a sheet of transparent squared paper. The paper is placed over the map so that one of the lines at the bottom edge of the paper is over the line on the map along which the section of ground is required. The map, of course, is read through the transparency of the paper. The next step will be to draw a line on the paper in pencil between the two extremities of the section and then to mark off the contour intersection points, the points where the contours cut the line just drawn. Mark at each intersection point the height of the respective contour. Then choosing some convenient scale, using the squares of the paper to represent any given number of feet or metres, vertical lines are raised at each contour intersection point in proportionate height to the contour it represents. Thus, if the contour was, say, 35 metres and a scale of one square to 5 metres was being used, the vertical line would be seven squares high. On joining the tops of all the lines so drawn by an even curve the outline of the section of ground required is obtained.

If no transparent paper is available ordinary paper can be used by copying off the exact length of the line of the section from the map and proceeding as before. It must be remembered that a section does not give the true angle of slope of hill features. The angle of slope would be correct if the vertical scale used were the same as the linear scale of the map, but generally the vertical scale has to be exaggerated as the

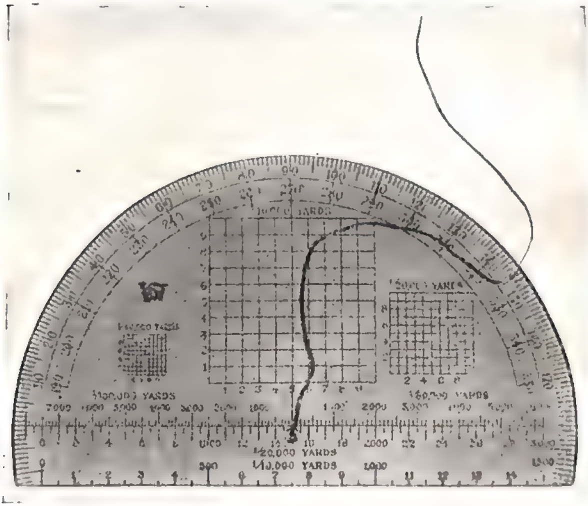
heights of hills generally bear such a small ratio to horizontal distances on the earth's surface.

Road or river sections can be made by following the straights and bends of the road or river and drawing the vertical lines according to heights, from the contours as above. If the general level is very great it is often necessary to deduct the lowest height of the ground from each contour height and make the vertical scale on the difference. Thus if the height of the ground of which the section is required is, say, between 300 and 400 feet one could deduct 300 from each height. Then smaller figures would be left, the small differences between which would be more accentuated by the vertical scale used than if they were shown on a scale suitable for fitting such large figures as 300 to the size of the paper available.

CHAPTER 8

Reading and Plotting Angles

Protractors are of two kinds generally, the wooden or opaque celluloid kind, and the transparent celluloid pattern. The latter are infinitely superior as their transparency allows



Semi-circular Protractor.

of the map being seen although the protractor covers it. To use the opaque protractor a line must be drawn on the map between the points to which the bearing or angle is being measured. This spoils the map. The semi-circular transparent protractor is generally provided with a catgut strand which is stretched to the point on the map to which the angle is being measured.

Where the catgut crosses the circumference of the protractor the angle is read. Thus there is no necessity to draw lines on the map when the distance to the point is either greater or less than the width of the protractor.

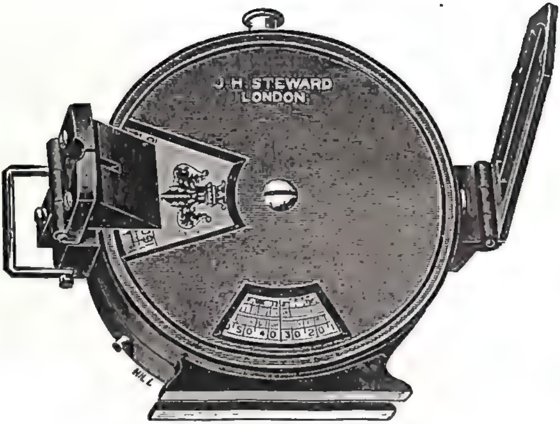
To read a bearing of one point to another on a map the protractor edge must be placed parallel to the vertical grid lines of the map and the small arrow placed on the first point. The catgut is stretched to the second point and the angle read. Note whether the vertical grid lines of the map are quite parallel to the North and South. If not make the necessary allowance in the reading.

If the protractor has to be on the right of the vertical line, that is, the second point to which the bearing is being taken is on the right or East of the first the angle will be between 0° and 180° and the outer graduations of the protractor will be read. If the protractor has to be placed on the left of the line or West, the reading will be between 180° and 360° and the inner set of protractor readings must be used.

Bearings, it must be remembered, are always measured from left to right in the direction of the hands of a watch right away round from 0° to 90° or one quarter of a circle to a half and through three-quarters to the full circle, which is 360°.

In plotting angles, observe the same rule as regards the use of the protractor. If the angle is less than 180° put the protractor on the right of the line and mark off by the outside graduations. If over 180° put the protractor on the left of the line and use the inner set of graduations. The inner set, it will be seen, runs from 180° to 360°.

Direct and Reverse Bearings.—If the bearing from "A" to "B" is, say, 30°, this will be called the direct bearing. The reverse bearing (or bearing of "B" to "A") will be 30° + 180°. Thus the rule is, if the bearing is less than 180°, to find the reverse bearing add 180°. If more than 180° deduct 180°.



The Prismatic Altazimuth.

This instrument measures angles in horizontal and vertical planes. The instrument consists of a compass combined with a clinometer and is used either in the hand or on a tripod. Both instruments are read through the same prismatic lens. An object is sighted and the angle read simultaneously without removing the eye from the prism. Slopes, gradients and levels can also be read from an index line in connection with the base which forms a plane of contact. The dials are divided to half degrees, and can be read to 15 minutes. A percentage or gradient scale is also divided on the clinometer. Size 2¾ inches diameter by ¾ inch thick. Check and lock stops.

CHAPTER 9

Gradients and Angles of Slope

The gradient or angle of slope can be read easily from a map from a close inspection of the contours. The contours need to be of narrow interval to do accurate work. Most large scale maps are contoured in 5 metre intervals and this is convenient.

A gradient is a slope expressed as a fraction thus $\frac{1}{300}$. This means that for every 300 units of distance horizontally the ground rises one unit vertically. The numerator and denominator must always be in the same unit of measure. If the linear scale of the map is in yards and the contouring in metres, then the metres would have to be converted to yards or *vice versa*. Metres are converted to yards by adding $\frac{1}{10}$. Yards are converted to metres by subtracting $\frac{1}{10}$.

An approximate rule for converting an angle into a gradient is

$$\text{Gradient} = \frac{\text{Angle in degrees}}{57}.$$

$$\text{Angle of slope in degrees} = \text{Gradient} \times 57.$$

This rule is practically correct up to 8°.

Angles of Slope.—A slope can be expressed as a fractional gradient or as an angle. The angle of slope can be calculated from the map either by:—

1. Trigonometry.

$$\text{The tangent of the angle of slope} = \frac{\text{V.I.}}{\text{H.E.}} \text{ in same measure.}$$

The V.I. expresses the "vertical interval" or difference in height between the two ends of the slope (read from the contours).

The H.E. expresses the "horizontal equivalent" or the horizontal distance between the two extremities of the slope. (This is found by measuring the distance between the two points on the map with the aid of the scale.)

The answer to the fraction which will be a small decimal gives the natural tangent of the angle of slope. The angle to correspond with this decimal number can be found by reference to a book of mathematical tables.

A trigonometrical calculation gives an absolutely accurate answer. However, for all ordinary purposes the simplest way to find an angle of slope is to use either of these formulae:—

1 Angle in degrees $= \dfrac{\text{V.I. (in feet)} \times 19{\cdot}1}{\text{H.E. (in yards)}}$.

N.B.—19·1 is often taken as 20 to simplify the calculation, but 19·1 is the accurate factor.

2. Angle in degrees $= \dfrac{\text{V.I.} \times 60}{\text{H.E.}}$.

V.I. and H.E. being in the same unit, yards, feet, metres, etc.

3. Angle in degrees $= \dfrac{\text{V.I. (metres)} \times 63}{\text{H.E. (yards)}}$.

N.B.—This formula is convenient for calculating when the map is contoured in metres, but the scale is in yards as in some 1: 10,000 maps.

4. The angle in minutes $= \dfrac{\text{V.I. (yards)} \times 3{,}400}{\text{H.E. (yards)}}$.

One can, of course, make any formula one likes to suit one's purpose according to what measures one finds the V.I. and H.E. in, by manipulating the standard topographical formula.

$$\frac{\text{V.I. feet} \times 19{\cdot}1}{\text{H.E. yards}}.$$

However, the above four formulae are the most generally useful.

TABLE OF GRADIENTS, CORRESPONDING TO VARIOUS ANGLES OF SLOPE

Angles	Gradients	Angles	Gradients
30′	1/114	5° 30′	1/10
1°	1/57	6° 30′	1/9
1° 30′	1/38	7° 30′	1/8
2°	1/26	8°	1/7
2° 30′	1/23	9° 30′	1/6
3°	1/19	11°	1/5
3° 30′	1/16	14°	1/4
4°	1/14	18°	1/3
4° 30′	1/13	26° 30′	1/2
5°	1/11	45°	1/1

ANGLES OF SIGHT OR SLOPE FOR DIFFERENT HEIGHTS AND DISTANCES

H.E. in yards: VI in metres.

	H.E. yards (distance)	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300
VI. METRES (height).	5 ..	1° 3′	47′	38′	31′	27′	23′	21′	19′	17′	16′	14′
	10 ..	2° 5′	1° 34′	1° 15′	1° 3′	54′	47′	42′	38′	34′	31′	29′
	15 ..	3° 8′	2° 21′	1° 53′	1° 34′	1° 21′	1° 11′	1° 3′	57′	51′	47′	43′
	20 ..	4° 10′	3° 8′	2° 31′	2° 5′	1° 47′	1° 34′	1° 24′	1° 15′	1° 8′	1° 3′	58′
	25 ..	5° 14′	3° 55′	3° 8′	2° 37′	2° 15′	1° 58′	1° 45′	1° 34′	1° 25′	1° 18′	1° 12′
	30 ..	6° 14′	4° 42′	3° 45′	3° 8′	2° 41′	2° 21′	2° 5′	1° 53′	1° 42′	1° 34′	1° 27′
	35 ..	7° 16′	5° 28′	4° 23′	3° 40′	3° 8′	2° 45′	2° 27′	2° 12′	2°	1° 50′	1° 41′
	40 ..	8° 19′	6° 15′	5° 1′	4° 10′	3° 35′	3° 8′	2° 47′	2° 31′	2° 17′	2° 5′	1° 55′
	45 ..	9° 20′	7°	5° 38′	4° 42′	4° 3′	3° 31′	3° 8′	2° 49′	2° 34′	2° 21′	2° 10′
	50 ..	10° 19′	7° 47′	6° 14′	5° 14′	4° 28′	3° 55′	3° 29′	3° 8′	2° 51′	2° 37′	2° 25′
	55 ..	11° 22′	8° 37′	6° 54′	5° 57′	4° 55′	4° 18′	3° 49′	3° 27′	3° 8′	2° 53′	2° 39′
	60 ..	12° 20′	9° 19′	7° 29′	6° 14′	5° 5′	4° 42′	4° 10′	3° 45′	3° 25′	3° 8′	2° 55′
	65 ..	13° 19′	10° 4′	8° 6′	6° 46′	5° 48′	5° 1′	4° 31′	4° 8′	3° 42′	3° 23′	3° 8′
	70 ..	14° 20′	10° 51′	8° 44′	7° 16′	6° 15′	5° 28′	4° 53′	4° 23′	3° 59′	3° 40′	3° 23′
	75 ..	15° 18′	11° 37′	9° 20′	7° 48′	6° 41′	5° 51′	5° 14′	4° 42′	4° 16′	3° 55′	3° 37′
	80 ..	16° 17′	12° 21′	9° 58′	8° 19′	7° 8′	6° 15′	5° 34′	5° 1′	4° 33′	4° 10′	3° 52′

ANGLES OF SIGHT OR SLOPE FOR DIFFERENT HEIGHTS AND DISTANCES—*continued*

VI. METRES (height). H.E. yards (distance)	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500
5	13′	12′	12′	11′	10′	10′	9′	—	—	—	—	—
10	27′	25′	23′	22′	21′	20′	19′	—	—	—	—	—
15	40′	38′	35′	33′	31′	29′	28′	—	—	—	—	—
20	54′	50′	47′	44′	42′	40′	38′	36′	34′	32′	31′	30′
25	1° 7′	1° 3′	59′	56′	53′	50′	47′	45′	43′	41′	39′	38′
30	1° 21′	1° 15′	1° 11′	1° 7′	1° 3′	1°	57′	54′	51′	49′	47′	45′
35	1° 34′	1° 28′	1° 22′	1° 18′	1° 14′	1° 10′	1° 6′	1° 3′	1°	57′	55′	53′
40	1° 47′	1° 40′	1° 34′	1° 29′	1° 24′	1° 19′	1° 15′	1° 11′	1° 8′	1° 5′	1° 3′	1° 1′
45	2° 1′	1° 53′	1° 46′	1° 40′	1° 34′	1° 29′	1° 25′	1° 21′	1° 17′	1° 14′	1° 11′	1° 8′
50	2° 15′	2° 5′	1° 58′	1° 51′	1° 45′	1° 39′	1° 34′	1° 29′	1° 25′	1° 22′	1° 18′	1° 15′
55	2° 28′	2° 18′	2° 9′	2° 2′	1° 55′	1° 49′	1° 44′	1° 39′	1° 34′	1° 30′	1° 26′	1° 23′
60	2° 41′	2° 31′	2° 21′	2° 13′	2° 5′	1° 59′	1° 53′	1° 47′	1° 42′	1° 38′	1° 34′	1° 31′
65	2° 55′	2° 43′	2° 33′	2° 24′	2° 16′	2° 9′	2° 2′	1° 56′	1° 51′	1° 46′	1° 42′	1° 38′
70	3° 8′	2° 56′	2° 45′	2° 35′	2° 27′	2° 19′	2° 12′	2° 5′	2°	1° 55′	1° 50	1° 46′
75	3° 22′	3° 8′	2° 56′	2° 46′	2° 37′	2° 29′	2° 21′	2° 15′	2° 8′	2° 2′	1° 58′	1° 53′
80	3° 35′	3° 21′	3° 8′	2° 57′	2° 47′	2° 39′	2° 31′	2° 24′	2° 17′	2° 11′	2° 5′	2° 1′

Angles of Sight or Slope for Different Heights and Distances

H.E. in yards: VI in feet.

VI. Feet (height). H.E. yards (distance)	300	400	500	600	700	800	900	1,000	1,110	1,200	1,300	1,400	1,500	1,600
10	38′	29′	23′	19′	16′	14′	13′	12′	10′	10′	9′	8′	8′	7′
20	1° 16′	58′	46′	38′	33′	29′	26′	23′	21′	19′	18′	16′	15′	14′
30	1° 55′	1° 26′	1° 9′	58′	49′	43′	38′	35′	31′	29′	27′	25′	23′	21′
40	2° 33′	1° 55′	1° 32′	1° 26′	1° 7′	58′	51′	46′	42′	38′	35′	33′	31′	29′
50	3° 11′	2° 23′	1° 55′	1° 36′	1° 22′	1° 12′	1° 4′	58′	52′	48′	44′	41′	38′	36′
60	3° 49′	2° 52′	2° 18′	1° 55′	1° 38′	1° 22′	1° 16′	1° 9′	1° 3′	58′	53′	49′	46′	43′
70	4° 27′	3° 20′	2° 41′	2° 14′	1° 55′	1° 41′	1° 30′	1° 20′	1° 13′	67′	1° 2′	58′	53′	50′
80	5° 5′	3° 49′	3° 3′	2° 33′	2° 14′	1° 55′	1° 42′	1° 32′	1° 24′	1° 16′	1° 11′	1° 7′	1° 1′	58′
90	5° 43′	3° 17′	3° 26′	2° 52′	2° 28′	2° 9′	1° 55′	1° 44′	1° 34′	1° 26′	1° 20′	1° 14′	1° 9′	1° 4′
100	6° 20′	4° 46′	3° 49′	3° 11′	2° 44′	2° 23′	2° 7′	1° 55′	1° 44′	1° 36′	1° 28′	1° 22′	1° 16′	1° 12′
110	6° 58′	5° 21′	4° 12′	3° 30′	3° 0′	2° 37′	2° 20′	2° 6′	1° 55′	1° 45′	1° 37′	1° 30′	1° 24′	1° 19′
120	7° 36′	5° 43′	4° 35′	3° 49′	3° 16′	2° 52′	2° 33′	2° 18′	2° 5′	1° 55′	1° 46′	1° 38′	1° 32′	1° 26′
130	8° 19′	6° 10′	4° 58′	4° 8′	3° 33′	3° 6′	2° 46′	2° 29′	2° 15′	2° 5′	1° 55′	1° 47′	1° 39′	1° 35′
140	8° 52′	6° 39′	5° 20′	4° 27′	3° 55′	3° 20′	3° 59′	2° 41′	2° 26′	2° 14′	2° 4′	1° 55′	1° 47′	1° 41′
150	9° 28′	7° 8′	5° 43′	4° 46′	4° 5′	3° 36′	3° 11′	2° 52′	2° 36′	2° 23′	2° 12′	2° 3′	1° 55′	1° 47′
160	10° 5′	7° 36′	6° 7′	5° 5′	4° 22′	3° 49′	3° 24′	3° 3′	2° 47′	2° 33′	2° 21′	2° 14′	2° 2′	1° 55′
170	10° 42′	8° 5′	6° 28′	5° 24′	4° 38′	4° 4′	3° 36′	3° 15′	2° 57′	2° 42′	2° 30′	2° 19′	2° 10′	2° 2′
180	11° 19′	8° 32′	6° 51′	5° 43′	4° 54′	4° 17′	3° 49′	3° 26′	3° 7′	2° 52′	2° 39′	2° 28′	2° 16′	2° 9′
190	11° 55′	8° 59′	7° 11′	6° 2′	5° 10′	4° 32′	4° 1′	3° 38′	3° 18′	3° 2′	2° 47′	2° 35′	2° 25′	2° 16′
200	12° 33′	9° 28′	7° 36′	6° 20′	5° 27′	4° 46′	4° 14	3° 49′	3° 28′	3° 11′	2° 56′	2° 44′	2° 33′	2° 23′

ANGLES OF SIGHT OR SLOPE FOR DIFFERENT HEIGHTS AND DISTANCES—*continued*

	H.E. yards (distance)	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	2,600	2,700	2,800	2,900	3,000
VI. FEET (height).	10	7′	6′	6′	6′	6′	5′	5′	5′	5′	4′	4′	4′	4′	4′
	20	14′	13′	12′	12′	11′	10′	10′	10′	9′	9′	9′	8′	8′	8′
	30	20′	19′	18′	17′	16′	16′	15′	14′	14′	13′	13′	12′	12′	12′
	40	27′	26′	24′	23′	22′	21′	20′	19′	18′	18′	17′	16′	16′	15′
	50	34′	32′	30′	29′	27′	26′	25′	24′	23′	22′	21′	21′	20′	19′
	60	41′	38′	36′	35′	33′	31′	30′	29′	28′	27′	26′	25′	24′	23′
	70	47′	45′	42′	40′	38′	36′	35′	34′	32′	31′	30′	29′	28′	27′
	80	54′	51′	48′	46′	44′	42′	40′	38′	37′	35′	34′	33′	32′	31′
	90	1° 1′	58′	54′	52′	49′	47′	45′	43′	41′	40′	38′	37′	36′	35′
	100	1° 8′	1° 4′	1° 1′	57′	55′	52′	50′	48′	46′	44′	43′	41′	40′	38′
	110	1° 14′	1° 10′	1° 6′	1° 3′	1° 0′	57′	55′	53′	50′	49′	47′	45′	44′	42′
	120	1° 21′	1° 16′	1° 13′	1° 9′	1° 5′	1° 3′	1° 0′	58′	55′	53′	51′	49′	47′	46′
	130	1° 28′	1° 23′	1° 18′	1° 15′	1° 11′	1° 8′	1° 5′	1° 2′	1° 0′	58′	55′	52′	51′	50′
	140	1° 35′	1° 30′	1° 24′	1° 20′	1° 16′	1° 13′	1° 10′	1° 7′	1° 4′	1° 2′	1°	68′	55′	53′
	150	1° 41′	1° 36′	1° 31′	1° 26′	1° 22′	1° 18′	1° 15′	1° 12′	1° 9′	1° 6′	1° 4′	1° 1′	59′	58′
	160	1° 48′	1° 42′	1° 37′	1° 32′	1° 20′	1° 24′	1° 20′	1° 16′	1° 13′	1° 11′	1° 8′	1° 7′	1° 3′	1° 1′
	170	1° 57′	1° 48′	1° 42′	1° 37′	1° 33′	1° 29′	1° 25′	1° 21′	1° 18′	1° 15′	1° 12′	1° 10′	1° 7′	1° 5′
	180	2° 1′	1° 55′	1° 49′	1° 44′	1° 38′	1° 34′	1° 30′	1° 26′	1° 23′	1° 20′	1° 16′	1° 14′	1° 11′	1° 9′
	190	2° 8′	2° 1′	1° 54′	1° 49′	1° 44′	1° 39′	1° 35′	1° 31′	1° 27′	1° 24′	1° 21′	1° 18′	1° 15′	1° 12′
	200	2° 15′	2° 7′	2° 1′	1° 55′	1° 49′	1° 44′	1° 40′	1° 36′	1° 32′	1° 28′	1° 23′	1° 22′	1° 19′	1° 16′

CHAPTER 10

The Table of Horizontal Equivalents

This table is a useful aid to map reading, although its main use is in sketching and rapid contouring.

Suppose an observer were using a map which had no contours or in which relief were indicated by hachures and spot levels, as is frequently the case in foreign maps. By means of this table he could determine how high surrounding objects were above or below him.

From a position "A" the observer looks down to an object "B" and measures the angle of depression with a clinometer to be 2° 30′. He measures the distance A to B by the map scale, say, 184 yards. This distance AB is the Horizontal Equivalent and from the table the vertical interval corresponding to the H.E. of 184 yards and angle of slope of 2° 30′ is seen to be 24 feet.

The utility of this table for sketching and contouring will be obvious. Suppose a sketcher has fixed on his paper the positions of all his ruling points by triangulation or by any other method. Then by means of the table of Horizontal Equivalents he can determine the relative heights of all the ruling points above or below his datum level by observing the angles of slope to them with a clinometer. Finally, having fixed the heights as well as the positions of his ruling points, he can easily sketch in the contours to suit those heights according to the shape of the ground.

Note.—If the H.E. happens to be greater than any given in the table, then halve it and find V.I. to correspond and multiply that V.I. by 2, etc.

CONTOURING TABLE

Horizontal equivalents (in yards) corresponding to different VI and Angles of Slope

Angle of Slope. Feet	Vertical Interval (in Feet) 5	10	15	20	25	30	35	40	45	50
30′	190	380	570	760	950	1,150	1,300	1,500	1,700	1,900
1°	95	190	285	380	480	570	660	760	860	960
1° 30′	64	125	190	255	320	380	450	510	570	630
2°	48	95	140	190	240	285	335	380	430	480
2° 30′	38	76	115	150	190	230	265	305	340	380
3°	32	64	95	125	160	190	225	255	285	320
3° 30′	27	54	82	110	135	165	190	215	245	270
4°	24	48	72	95	115	140	165	190	215	240
4° 30′	21	42	64	84	105	125	145	170	190	210
5°	19	38	56	76	95	115	130	150	170	190
5° 30′	17	35	52	69	87	105	120	140	155	175
6°	16	32	48	64	80	95	110	125	140	160
6° 30′	15	30	44	58	74	88	105	115	130	145
7°	14	27	41	54	68	82	95	110	125	135
7° 30′	13	25	38	50	63	76	89	100	115	125
8°	12	24	35	48	58	72	84	95	105	115
8° 30′	11	22	33	44	55	68	79	88	100	110
9°	11	21	32	42	53	64	75	84	95	105
9° 30′	10	20	30	40	50	60	70	78	90	100
10°	9	19	28	38	48	56	66	76	85	95

CONTOURING TABLE—*continued*

Horizontal equivalents (in yards) corresponding to different VI and Angles of Slope—*continued.*

		Vertical Interval (In Feet)									
	Feet	55	60	65	70	75	80	85	90	95	100
Angle of Slope.	30′	—	—	—	—	—	—	—	—	—	—
	1°	1,050	1,150	1,250	1,300	1,400	1,500	1,600	1,700	1,800	1,900
	1° 30′	710	760	850	900	950	1,000	1,100	1,150	1,200	1,300
	2°	530	570	630	660	720	760	810	860	900	950
	2° 30′	420	460	495	530	570	610	650	690	730	760
	3°	350	380	410	450	480	510	540	570	600	630
	3° 30′	295	325	355	380	415	440	465	490	520	550
	4°	265	285	310	335	360	380	405	430	455	480
	4° 30′	230	255	270	295	320	335	355	380	400	420
	5°	210	230	250	265	285	305	320	340	360	380
	5° 30′	190	205	220	240	260	275	295	315	330	345
	6°	175	190	210	225	240	255	270	285	305	320
	6° 30′	165	175	190	210	220	235	250	265	275	290
	7°	155	165	175	190	205	215	230	245	255	270
	7° 30′	135	150	160	175	190	200	215	230	240	250
	8°	125	140	150	165	175	190	200	215	225	240
	8° 30′	120	130	140	155	165	180	190	200	210	220
	9°	115	125	135	145	160	170	180	190	200	210
	9° 30′	110	120	125	135	150	160	170	180	190	195
	10°	105	115	120	130	140	150	160	170	180	190

CHAPTER 11

Scales of Horizontal Equivalents

THEIR USES AND CONSTRUCTION

A useful adjunct to a map is a scale of Horizontal Equivalents. It has been seen in the chapter on "Representation of Relief of Ground in Maps," that contours afford an accurate indication of slopes by their relative spacing. Thus contours at wide intervals indicate gradual slopes while contours very close to one another indicate relatively steep slopes. The object of a scale of Horizontal Equivalents is to measure the actual degree of slope from the distance between the contours.

Thus it is required to find the slope of the ground at a certain point. On the edge of a sheet of paper is marked off the distance between the two adjacent contours at that point on the map. The paper is then adjusted to the scale to the division that fits it the nearest and the angle of slope is read.

The construction of these scales is based on the principle that a slope of 1° corresponds to a gradient of 1 in 57·3. In other words this rule says that for a slope of 1° the H.E. is always 57·3 times the V.I. Sometimes the factor 60 is used instead of 57·3 for convenience of calculation, and the error introduced is not considerable in scales up to 6 inches to 1 mile. But in larger scales the factor 57·3 should always be used.

To construct a scale of Horizontal Equivalents for any map use this formula:—

$$\text{H.E. of } 1^\circ = \text{V.I. of map} \times 57{\cdot}3.$$

Work this out and plot it by the scale of the map.

The H.E. of 2° will be half that of 1°, for 3° one-third, etc.

Example.—Construct a scale of Horizontal Equivalents for a map 6 inches to 1 mile contoured at 20 feet vertical interval.

$$\begin{aligned} \text{H.E. of } 1^\circ &= \text{V.I. of map} \times 57{\cdot}3 \\ &= 20 \times 57{\cdot}3 \\ &= 1{,}146 \text{ feet} = 382 \text{ yards.} \end{aligned}$$

Measure off a distance 382 yards on the scale of the map and this will be the horizontal equivalent for 1°.

For 2° halve this distance and add it to the end of the H.E. of 1°; proceed similarly for 3°, 4°, 5°, etc. The scale will seldom need to extend beyond 10°.

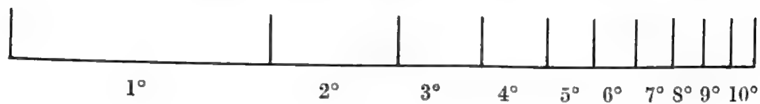
NOTES.—1. It is not absolutely correct to take the H.E. for 2° as half that of 1°, and that of 3° one-third of 1°, etc., but the error introduced is almost negligible for angles up to 8°.

2. Scales of H.E. are mainly useful in determining steepest slopes or slopes of small stretches of ground. The slope over longer distances is best measured by calculation, using the formulae for angle of slope or by means of the table of angles of slope.

Example of H.E. Scale: see next page.

Scale of Horizontal Equivalents

(For a Map 6 inches to 1 mile contoured at 20 feet V.I.)



Scale 6 inches to 1 mile

CHAPTER 12

The Mutual Visibility of Points

There are three practical methods of determining from a map whether two points are mutually visible.

The first method of gradients is used when there is only one, or not more than two points which may cause an obstruction in the line of sight. If, however, there are several doubtful points, all of which have to be tested, then the two other methods are more convenient. Because in the gradient method a separate calculation has to be made for each obstructional point while in the second and third methods one diagram serves to test any number of points.

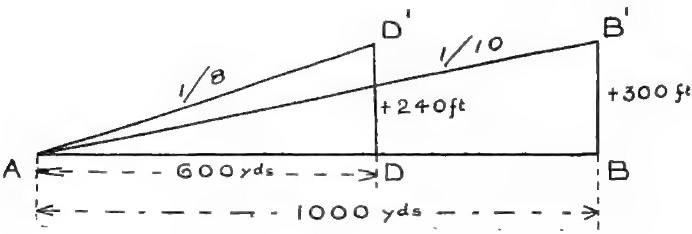


FIG. 13.

First Method. Gradients.—Join the two points A and B on the map by a faint pencil line and note the exact position on the line of the supposed obstructional point (D). Read the gradient uphill A to B which in the case of Figure 13 is—

$$\frac{300}{1{,}000 \times 3} = \frac{1}{10}.$$

Then read the gradient to D (uphill A to D)

$$\frac{240}{600 \times 3} = \frac{4}{30} = \frac{1}{8} \text{ nearly.}$$

It will be seen that the slope AD is steeper than the slope AB, therefore D would obstruct the line of sight and the two points A and B would be mutually invisible.

NOTE.—To simplify the calculation the gradient can be expressed as $\frac{\text{Height}}{\text{Distance}}$ without bringing height and distance to the same unit of measure since the factor for bringing them to the same unit enters into both calculations, and so if omitted affects both gradients equally.

Second Method. By a Vertical Section.—If a vertical section of the ground is drawn and the extremities of the section joined by a straight line this line will represent the line of sight. Then from the section it can be seen at once if the line of sight is obstructed by the outline of the ground at any point.

It will not be necessary to draw the complete section in most cases, but only of that part of the ground which it is thought may cause the obstruction.

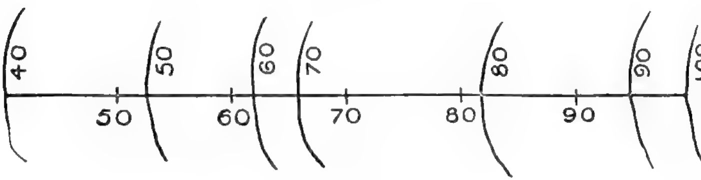


FIG. 14 (1).

Third Method.—This method allows of a number of points to be tested quickly and accurately for obstructing the visibility of one point from another. Figure 14 (1) represents a part of a map with 5-metre contours—it is required to test the mutual visibility of the two points A and B. Join the two points by a straight line. This line then represents the line of sight. Divide the line of sight into a number of parts equal to the number of vertical intervals that exist between A and B, and number each division correspondingly. Now, if when reading uphill any contour line cuts the line of sight **below** the division corresponding to the contour height then the ground at this point will rise above the line of sight and so form an abstruction. If the contour cuts **above** its respective division then this means that the ground does not rise up to the level of the line of sight, and so does not form any obstruction at that point.

To understand this clearly imagine a vertical section of the ground as in Figure 14 (2).

Take each contour in turn. Reading uphill from A to B the 50 contour cuts above the 50 division so the ground at this point does not obstruct the line of sight. This is apparent in the section where it is seen that the ground does not rise as high as that line.

Similarly for the 60 contour. But, on the other hand, the 70 contour, which cuts below its respective division on the

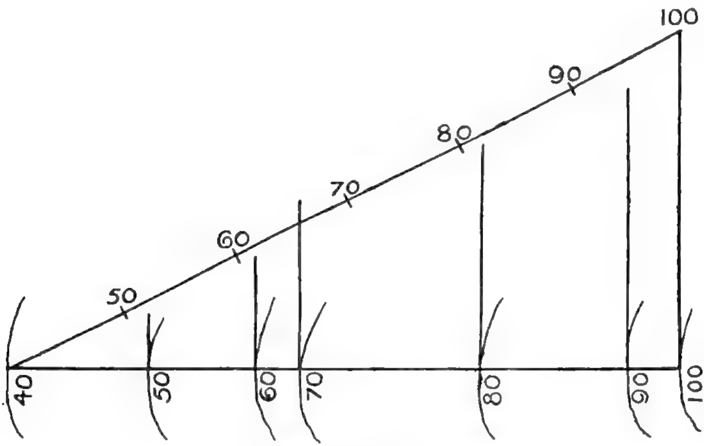


FIG. 14 (2).

line AB, does obstruct the line of sight. This is apparent from the section.

Lastly, the 80 and 90 contours cut above their respective divisions and so do not cause obstructions, and this can again be proved by referring to the section.

CHAPTER 13

Heights of Obstructions in the Line of Sight

Besides problems of the mutual visibility of points others that are interesting and useful to work out from maps are calculating the heights of obstructions in the line of sight. It may be required to find the exact height of an intervening hill top or of a wood above the line of sight, from one point on the ground to another; or again it may be required to find how high the line of sight passes above any object such as a bridge or house on the intervening ground when looking over a valley or undulation.

These problems are not difficult once the methods of solving them are seen; however, the speed of solving them is another matter. It is upon the speed at which they can be solved that their practical value depends. Therefore after seeing the methods it is essential to practise speed. With practice one easily becomes so skilled that one can solve problems of visibility and heights of obstructions by "reading" the answer and not calculating it. Ability to read such information from a map constitutes, as we have seen, skill in map reading.

The methods of reading or calculating the heights of obstructions are:—

First Method. By making a Vertical Section.—Note carefully on the line joining the two points the position of the obstruction; let this be "D" in Figure 15. It will not be necessary to make a complete section of the whole ground, but only of the three points, the extremities of the line and the obstruction.

Now if the extremities of the section be joined by a straight line. This line will represent the line of sight and DE will be the height of the obstruction above the line of sight. This

height can be read off by the scale used in making the vertical section.

NOTE.—Squared transparent paper is most convenient for this as the squares provide a ready made scale.

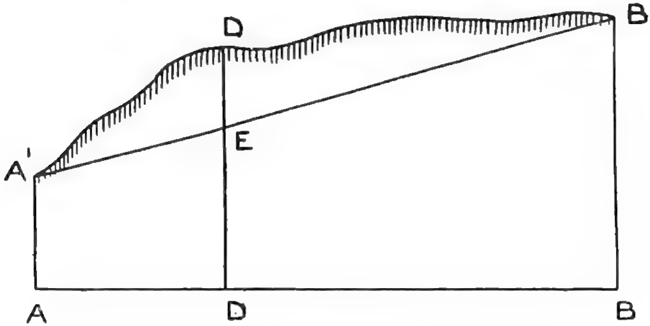


FIG 15.

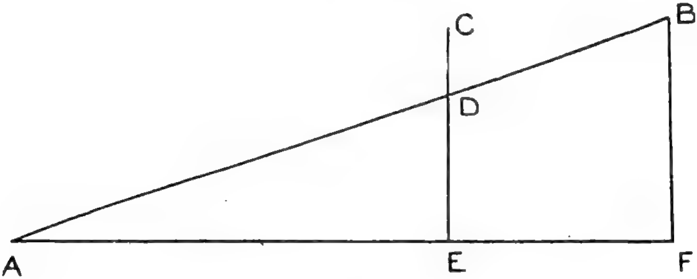


FIG. 16.

Second Method. Proportion method.—In Figure 16, suppose AB to be the line of sight and C to be the top of the obstruction. It is required to find the height CD, the height of C above the line of sight.

We know the height CE. This is the difference in height between C and A read from the contours of the map. Similarly

BF is the difference in height between B and A. If DE can be found CD will be obtained as this is CE less DE.

DE is found by proportion

$$\frac{DE}{AE} = \frac{BF}{AF}.$$

AE and AF are measured off the map by the scale being the distance between the respective points on the map.

$$DE = \frac{BF \times AE}{AF}.$$

From this CD is finally obtained—the height of the obstruction.

This method is quicker than drawing a section. It can be done in the head, on occasions when an approximate answer only is required, by comparing by eye the distances on the map. Thus if the obstruction is half-way to the other end of the line the height DE would be half the difference in height between A and B, if three-quarters the distance then it would be three-quarters the height. A rapid estimate can be obtained in this way easily and quickly which is an important advantage.

Third Method.—This is a quick method provided an angle of sight table is available as in Chapter 9.

See Figure 16.

Suppose AF = 2,000 yards.
AE = 1,200 yards.
BF = 25 metres.

Angle of sight from table = 47′.

An angle of 47′ gives a vertical rise of 15 metres in 1,200 yards. (The distance to the obstruction.)

Therefore DE = 15 metres.

Now CE is known (the height of C above A read from the map contours). So the height of the obstruction above the line of sight is found, CD.

$$CD = CE - DE$$

The same method applies of course for reading down hill.

NOTE.—Most large scale maps such as would be used for these problems are contoured in metres with a horizontal scale of yards as in the maps 1: 10,000 and 1: 20,000 of England. However, the angle of sight table for VI in feet is also given and can be used when required.

CHAPTER 14

Instruments Useful in Map Reading

THE PROPORTIONAL DIVIDER

This is an extremely useful instrument for map enlarging, for linear reduction from air photograph to maps, and for utilising map scales to measure distances on air photographs when photograph and map are of different scales.

The instrument consists of two pointed arms with a sliding and locking pivot that can be set to any marked graduation on the side of the instrument to give any ratio from 1: 1 to 1: 10 between the opening of the points of the double pointed arms.

When using the instrument to co-ordinate air photographs to a map of a different scale, the pivot is adjusted by trial and error until the opening of the points of the long arms and that of the short arms coincides with the distances respectively between two points on the photograph and the same points on the map. The divider thus becomes set to the correct proportion of scale between photograph and map and then can be continued to be used to (*a*) measure any distances on the photograph by the scale of the map (*b*) locate and plot the exact position of objects revealed in the photograph but not shown on the map—or vice versa.

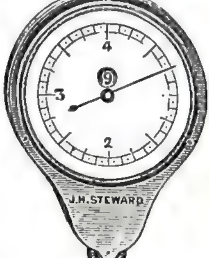
MAP AND ROUTE MEASURER

This little instrument provides an efficient and quick means of measuring the length of a winding road, railway or river on a map.

The indicator is first set to zero by turning the little serrated wheel at the base of the instrument with the finger; and the wheel is then run along the course of the road following all its curves. The instrument is then turned face-about in the hand and run along the scale of the map until the indicator hand is wound back to zero, at which position the measured distance becomes indicated on the map scale.

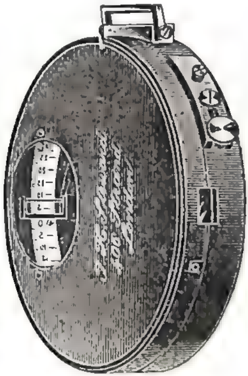
Aero
Hypsometer.

Proportional
Divider.



Map
and Route Measurer.

In one type of the instrument the dial is engraved with mileage scales ready for direct reading; but these, of course, can be used only when the scale of the dial is the same as that of the map. Another type has an open scale divided to 1/16 of an inch and registers complete revolutions up to ten—equivalent to a run of 40 inches. With both types the graduations may, of course, be disregarded and the instrument used merely in the manner of running out along the map and then back along the map scale.



THE MIRROR CLINOMETER

This instrument, which is easily carried, measuring two and a half inches diameter and half an inch thick, enables the user to take angles of sight and slope and read gradients by direct observation when an opportunity exists to do so on the ground. This direct observation may conveniently be combined with the use of the ready-reckoner tables given in this book for quickly determining the heights of obstructions in the line of sight, also for measuring heights when the map is not contoured, using for this purpose the table of H.E. given in Chapter 10.

A Clinometer and Pocket Telemeter can be used together for many useful purposes.

In the instrument a pinhole and a magnifying window allow simultaneously a sight on to a distant object and a magnified observation of the reading of the pendulum dial. This dial is graduated to single degrees, and visual estimation may easily be made to half a degree. The elevation scale is red and the depression scale is black. A locking stop is fitted to fix the pendulum when not in use.

Note also the use of the Prismatic Altazimuth, described on page 44.

POCKET SURVEYING TELEMETER

(Illustration: page 102.)

The Pocket Surveying Telemeter affords a rapid means of measuring distances. The Telemeter measures the two angles at the extremity of a base, forming a triangle with the object of which the range is required and gives the distance of the object without any calculation.

In a traverse or rout survey the position of points on either side of the route can be rapidly fixed. The distance separating any two objects can be determined, although the objects may be inaccessible or invisible from each other.

A paced base gives very approximate results, but where greater accuracy is aimed at a tape should be employed for measuring the base.

The range is read directly on the graduated scale in terms of units of the base, so that any system of measurement can be employed. By making the unit of measurement either short or long, distances of any length can be determined. The limit of distance that can be measured is governed by the length of base that can be employed and by the visibility of the object. The scale of distances is computed for a normal base of 20 units and is figured at every tenth division from 200 to 1,000, each division representing 10 units of distance. Results are given with great accuracy, the mean error working out at less than one per cent. In certain operations it may be convenient to employ a base of constant ratio to the distance, and the telemeter is adapted also for this system of measurement.

The instrument is furnished with a sighting telescope of moderate power. The size of the telemeter is 4½ inches long by 1½ inches diameter, and the weight 10 ounces.

THE STEWARD AERO HYPSOMETER

(Illustration: page 64.)

The Aero Hypsometer is an aneroid barometer or altimeter of special construction for use in an aeroplane, and is furnished with a rotary scale actuated by rack and pinion for indicating the height of the aeroplane above its starting point. The mechanism is so constructed that the effects of vibration are reduced to a minimum and the tremor of the index hand is hardly noticeable.

The altitude scale is plainly divided to every 200 feet with bold numerals indicating each 1,000 feet, a small 5 being engraved at each intermediate 500 feet. A fixed zero point on the dial indicates mean sea level.

The movement is compensated and is unaffected by change of temperature.

A leather strap passing through metal loops is sufficiently long to strap the instrument on to the coat sleeve or knee. The instrument is approximately 2 inches diameter and $\frac{5}{8}$ inch thick and weighs about 4 ounces.

Although its ceiling is limited, it has a good, fair range of height for air photography and surveying.

CHAPTER 15

The Modern Prismatic Compass

The prismatic compass is an ordinary compass fitted with a device for accurately reading the magneti bearings of objects. This device is in the form of a prism and sighting vane and is so made that the observer looking through the eye hole of the prism gets a direct view of the sighting vane cutting the object on which he is taking a bearing and at the same time sees a reflected image of the graduations of the dial at the bottom of the sighting vane.

This is the principle of the prismatic compass. There are many different forms of these compasses from the simplest to the most elaborate and perfected designs. The best type of compass is the liquid type and in fact this is almost the only kind for rapid use. The compass card being floated in liquid is very steady and soon comes to rest when taking a bearing, so a quick and accurate reading can be obtained. In the ordinary non-liquid types the compass card swings and oscillates so that the process of reading bearings is tedious and inaccurate. The advantage of the liquid over the non-liquid types more than justifies the extra cost of the former.

The prismatic compass consists essentially of two parts—the body and the cover. Inside the body is the compass card pivotted on a needle point and floating in liquid. Underneath the card is attached the magnetic needle. The compass card is graduated in two sets of graduations. The inner set is generally marked to every five degrees and is used for direct readings when using the compass in the hand like an ordinary compass. The outer set of graduations are the ones that are read through the prism. These are in single degrees and by eye bearings to half and a quarter of a degree can be estimated if the dial is steady as in the liquid types. On the card are marked the points of the compass, and it is an advantage to have the northern half of the disc black as in the illustration. The North point of the dial is indicated by a luminous arrow head.

The cover of the compass has a glass window on which is etched the sighting vane and at either end of the sighting vane are found two luminous patches which indicate the line

of the vane at night and give direction for night marching. These luminous patches sometimes have pin holes in them for the purpose of stretching a hair line or thread between the holes in case the glass and sighting vane get broken.

The prism is fitted with a focusing movement which allows it to be raised or depressed in order to get the dial graduations in correct focus. If the compass body is tilted for reading a bearing uphill the prism must be raised because the compass card which remains horizontal will be thrown out of focus. If reading downhill and the compass body is inclined downwards the prism will have to be depressed.

The brass ring is used to hold the compass with the thumb and forefinger.

The compass is provided with a revolving cover glass, which can be clamped by a screw at the side of the body. The revolving cover glass carries an index line sometimes called the lubber line and a scale of angles known as the Verner scale and these together comprise the night marching attachment. The design of the Verner scale differs in different makes of compasses, sometimes it is engraved round the outside of the body and the lubber line is set to any bearing on it by revolving the cover glass; but in the Steward Prismatic the Verner scale is on the cover glass itself and there is a patch of radium compound underneath so that bearings can be easily read and set by it at night time.

In modern instruments all the luminous parts are made of radium compound, which has the advantage of remaining permanently luminous, but in the older types luminous paint was provided and this was luminous only ofter exposure to light for some time before use. Luminous paint will not retain its luminosity after being charged for more than about eight hours, and its luminosity never approaches the brilliance of radium compound.

Another useful type of compass is the "Lensatic." The reading of the dial is effected through a lens instead of a prism, hence the name lensatic. The lens is erected and through it a magnified reading of the dial is obtained direct against a little black line on the inside of the body. The dial is slightly saucer shaped. The sighting vane is seen through a fine slit above the lens, and so a coincidence between the sighting vane and the dial graduations is obtained just the same as in the prismatic type.

Some advantages of the lens are simplicity and clearness since there is no prism to cast a shadow on the dial, and no focusing is needed.

The Steward Patent Liquid Luminous Prismatic Compass.

A Liquid and Luminous Prismatic Compass for taking and recording bearings by day or night, and for night marching, map reading and field sketching.

Luminosity is derived from a radio-active compound and is permanent.

The bowl of the compass is filled with liquid which is temperature controlled and the dial being completely immersed oscillations are damped down and the dial comes quickly to rest. Should air bubbles form they can be trapped in a special chamber.

The dial is divided to single degrees and bearings can be read to half a degree. An inner circle on the dial is divided

to every 5 degrees, and serves for map setting and plane tabling. A friction ring prevents slipping when the compass is used on a plane-table.

A rotary transparent scale of bearings is illuminated by a patch of radio-active compound, and can be set to the required bearing and read at might without the aid of artificial light. The scale is figured at every 10 degrees, the final zero being omitted to allow of large numerals.

A sighting line is etched on the glass window and two holes are drilled in the lid, so that should the glass get broken a horse-hair sight can be substituted.

Bearings can be very accurately taken by aligning the luminous line on to the object, turning the scale until the lubber line coincides with the North Point on the dial; and then reading the bearing from the scale over the illuminating patch. The author has taken bearings at night using the instrument in this way and then checked them with a prismatic compass by day and found the readings accurate to within a degree. Such accuracy is remarkable in taking bearings with any compass at night.

NOTE.—Light folding tripods can be obtained for compasses where steady and accurate work is required. These stands can also be obtained in the form of a walking stick.

The Mark VIII Luminous Prismatic Compass. (Dry.) Permanent luminosity by radio-active compound. Pearl dial divided to single degrees and can be read to ½ degrees through the prism, which has a sliding focusing adjustment. An inner circle on the dial is divided to every 5 degrees with the numerals arranged as on the dial of an ordinary compass for map-setting. The N point is indicated by a luminous arrow head on the dial. A scale of degrees is engraved on the outside of the compass box for use in connection with the adjustable luminous direction index for night marching on the "Verner" principle.

A sighting line is etched on the glass window in the lid, and two small holes are pierced at each end of the line so that if the glass window gets broken a horse hair sight can be substituted. Luminous patches at the ends of the sighting line serve for sighting, and indicating the line of march at night. When the lid is closed the dial is automatically locked. A friction ring on the base prevents slipping when the compass is used on a plane-table. The outside diameter of the compass is 2 inches. (Illustration: see next page.)

Mark VIII Prismatic Compass
(Verner Principle).

The Prismatic Altazimuth.—A compass combined very usefully with a clinometer—described and illustrated on page 44.

CHAPTER 16

Magnetic Variation

The true meridian is a line running through the earth through the North and South Poles and any point on the earth's surface, say London. A magnetic meridian is a similar line only it passes through the magnetic North and

FIG 17.—Magnetic Variation.

South Poles. From the fact that the magnetic North Pole is situated in North Canada and not at the true pole, it will be seen, as in the diagram, that the two meridians true and magnetic, are at an angle to one another. This angle is called the magnetic variation. It must be noticed also that the position of the magnetic poles is not fixed. The magnetic poles are always changing their position although in a small degree, so this causes the magnetic variation to be a variable quantity. One notices this on maps where the variation is shown as, say, 16° 21′ with an annual decrease of, say, 5′ E.

There is another point to be noticed. If the position is changed from London to Paris, it will be seen clearly from the diagram that the magnetic variation changes also—the angle is less.

The constant change of the magnetic variation for different localities on the earth obliges one to determine the magnetic variation of one's compass before one can use it for measuring bearings or for any other use. Practically, one may do either of these two things:—

(1) Either determine the magnetic variation of the compass afresh for each different locality one visits.

(2) Find once and for all the "error" of the compass; then to find the magnetic variation, all that is needed will be to correct the magnetic variation given on the map of that locality by the constant error of the compass.

N.B.—All compasses have slight errors of their own. The fact of a compass having an error does not matter at all or detract from the compass as long as the existence and amount of that error is known.

CHAPTER 17

To Find the Magnetic Variation of the Compass

The magnetic variation of the compass can be found by determining the difference between the true bearing of one point from another measured from a map and the magnetic bearing of one from the other measured with a compass on the ground.

Thus: (1) Take any two points A and B on the map which are mutually visible. It is best to choose only prominent objects and ones whose position one can be certain of as being quite accurate on the map. Churches and cross roads are good objects. Measure the true bearing of A to B by drawing a line parallel with the true North line of the map through A and measuring the angle with a protractor between this line and the line A to B.

Suppose this angle to be 31½°

(2) Go to the position A on the ground and with the compass measure the magnetic bearing to B. Say this comes to 48°.

Make a diagram of these two bearings, the vertical line of the circle representing true North. Thus (see Fig. 18).

The line AB is drawn at 31½° to true North. Then to get the angle of 48° with the line AB, the line with the arrow will have to be drawn. This line will be the magnetic North and South line. From the diagram the magnetic variation is apparent, 16½° W.

Though in this case the question resolved itself into merely subtracting the true from the magnetic bearing the problem is not always so simple. Take the case when the true bearing might have been 354° and the magnetic 10½°, the variation will still be 16½° W. This is apparent if one *invariably draws the diagram.* It is simple to do and obviates all possibility of error.

The diagram will also show each time automatically if the variation is East or West.

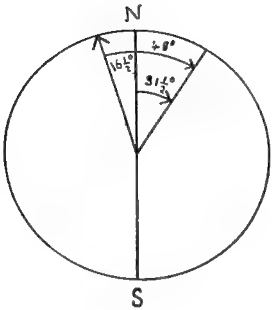


FIG. 18.

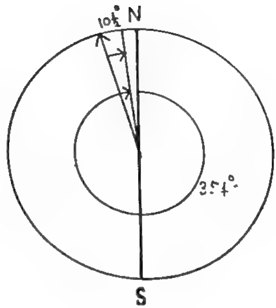


FIG. 19.

The Error of the Compass

The error of the compass is the difference between the magnetic variation of the compass and the true magnetic variation for the same locality. The "true" magnetic variation being the actual angle between the true and magnetic meridians. The error of the compass can, of course, be found by subtracting one from the other. The error of the compass found in this manner is always a constant error. Thus if the error were $\frac{1}{2}°$ W. and the observation had been made in London, on going to another country and consulting a map of that country which marked the magnetic variation as, say 4° W., then the variation of the compass would be found by adding the $\frac{1}{2}°$ error, making it $4\frac{1}{2}°$ W. for this second locality.

All compasses have slight errors of their own generally, but this, as mentioned before, does not detract from the value of the compass. One needs to know the error and make allowance for it.

CHAPTER 18

Bearings, and Converting True to Magnetic Bearings, and *vice versa*

The bearing of an object is the angle between the meridian and the line from the observer's position to the object.

If the angle is measured from the true meridian, that is true North and South, the bearing would be called a true bearing. If measured from the magnetic meridian it would be called the magnetic bearing.

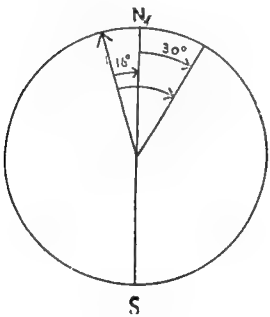


FIG. 20.

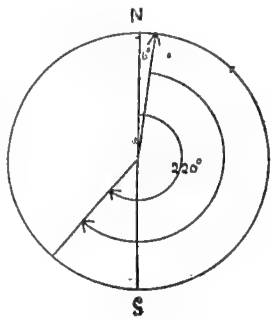


FIG. 21.

Bearings are always measured from left to right in the direction of the hands of a watch. They are measured from 0° to 360° or a full circle.

The conversion of true to magnetic bearings and *vice versa* is often confusing. One forgets whether to add or deduct the magnetic variation. It is far the simplest and best plan to make it an invariable rule to do the conversion graphically. Draw a circle and mark in the True North

as a vertical diameter, thus (see Fig. 20) to convert a true bearing of 30° to magnetic, magnetic variation being 16° W.

Mark in the magnetic variation as 16° W. of the true North and South line. Draw the angle of 30° representing the true bearing. From the diagram the magnetic bearing is obviously 46°.

Another example.—To convert a magnetic bearing of 220° to true bearing. Magnetic variation 6° E. (see Fig. 21). From the diagram the true bearing is apparent, 220° + 6° = 226°.

CHAPTER 19

Night Marching on Compass Bearings

In the prismatic compass, the night marching device consists essentially of:—

(1) A luminous revolving index on the glass cover of the compass which can be set to a figure giving the required bearing to march by.

(2) A luminous arrow head on the compass dial.

(3) A luminous indicating line to indicate the line of march.

One can tabulate the procedure of using the compass for night marching thus:—

(i) Expose the compass to daylight, preferably sunlight for one hour before night. This gives the luminous paint of the compass a charge of luminosity, which is retained for some 10 hours or so The best compasses are, of course, provided with permanent radio active material instead of luminous paint. This is, of course, a convenience, practically a necessity. The lensatic compass has radium points which shine in the dark with astonishing brilliance.

(ii) Convert the true bearings to magnetic bearings according to the magnetic variation of the compass. The directions to march will usually be taken and measured from a map with a protractor as true bearings, since the true meridians of the map will be used to measure from.

(iii) Measure distances carefully from the map and tabulate the data in a note book. The figures may conveniently be written on a Steward's Luminous Memo Tablet.

T. B.	Yards	M. B.	Paces
215°	560		
23°	400		
etc.	etc.		

(iv) At the position to start the march set the revolving index on the cover of the compass to the first bearing to march by. The scale of figures are generally round the outside of the body in the prismatic types and on the face in the lensatic. The radium points in the latter type enable one to set the index without lighting a match in the dark.

FIG. 22.—How the Compass gives direction in Night Marching.

(v) Holding the compass flat, with the cover also opened flat, twist it round until the index is brought to register exactly with the arrow head on the dial. The direction line on the cover will then indicate the direction to march (see Fig. 22).

GETTING DIRECTION

There are three methods of controlling one's direction.

(1) By a reference object.

(2) By the use of an assistant.

(3) By the direct march.

(1) The use of a reference object.—This is the usual method as it is the most accurate, and can generally always be employed. The night is seldom so dark that absolutely nothing can be seen. The method consists in picking out some prominent object which is in direct prolongation of the line of direction that the compass indicates. By looking down at the compass and prolonging the line one can accurately pick out an object to march on that comes in that line. The objects that appear most distinctly are those on the skyline, such as trees, edges of woods, indentations and gaps in the skyline. In choosing trees there is always a chance of mistaking the tree for another if one does not keep one's eye fixed on it all the time.

Thus when a reference object has been chosen the compass can be closed up and the march started on that object as guide for the requisite number of yards or paces according to the data noted.

(2) The second method, of using an assistant, is one that is extremely slow and tedious, but one which has to be resorted to with the ordinary type of compass when the night is too dark to pick up reference objects as in the first method. Here an assistant going on in front with white paper on his back is used as a reference object. The man with the compass controls the direction of the assistant and halts him when he has gone as far as he can without being out of sight. The compass man then comes up on the assistant, counting the paces, and directs the assistant on again.

(3) The method of the direct march is simply following the line of the compass cover indicating the line of advance, holding the compass in the hand all the time, and being guided by it. The index and arrow head are kept in register

all the time while advancing and the observer follows directly the direction the compass indicates.

The direct march can be employed, of course, only with compasses with dials in oil because with the ordinary types

The "Steward" Liquid Luminous Brigade Compass.

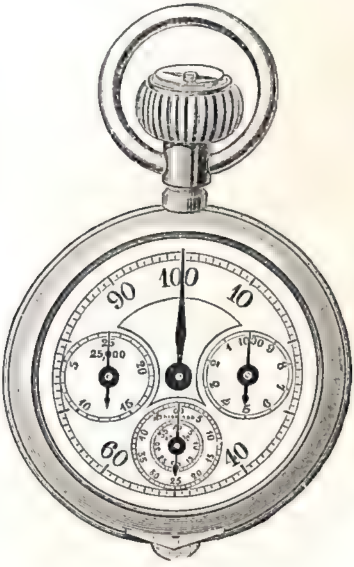
of compass with pivoted dials, the dials swing about so freely that it is impossible to keep the index and arrow head in register while walking. Therefore direction cannot accurately be ascertained. But with the oil compass the dia1

is so steady always that walking does not upset or cause the dial to swing.

The advantages of the direct march are, of course—

(1) Speed.

(2) Makes marching through woods and over deserts possible when there are no reference objects available and in the case of a wood, the use of an assistant is impossible.



Paceometer.

MAKING A SCALE OF PACES—THE PACEOMETER

Distances measured from a large scale map for night marching will generally be in yards. It is obviously inconvenient to pace yards, especially in the dark, when one cannot see where one's foot is falling, so it is useful to ascertain how many paces one takes to 100 yards at night and convert

one's yards' measurements to paces according to that scale. The scale should be determined by pacing over the same kind of ground as is to be covered at night. In this connection a paceometer is extremely useful. This is a little instrument which, when pinned to the breast and allowed to hang vertically, but not to shake about, records without mistake every pace the wearer takes. A paceometer (or "passometer") records the number of paces taken, irrespective of the length of the pace. A pedometer records each pace as one yard. This is inconvenient.

Notes.—(1) When using stars as reference objects, choose stars at an elevation of not over 30° above horizon, otherwise the star will change its bearing too quickly. Stars of elevation up to 30° will not change their bearing more than 5° in 20 minutes.

2. The addition of a time scale to a map for the purpose of measuring distances for night marching is always very useful. The method of constructing such scales is given in the chapter on "scales."

CHAPTER 20

Night Marching by Stars

Night marching and finding one's way at night by compass and stars is a most fascinating subject and one full of practical value at all times. The stars have been used from the earliest times as guides by travellers and mariners, but since the compass was introduced stars have become only a supplementary method to the compass for finding one's way. The two methods are closely connected, and a knowledge of the stars is a necessary supplement to compass work.

The main value of knowing the stars is that you can use the heavens as your compass and recognise your bearings and directions at any time. A simple knowledge of the stars will prevent a man from ever completely losing his way at night. Many people, however, are quite ignorant of the names, positions and movements of the stars and so they know nothing of the simple guides that nature provides.

The first thing is to understand the movements of the stars and their apparent rotation round the earth. In reality it is the earth which rotates, the stars being fixed in the sky. The sun is one of the stars and the earth rotates round this fixed star.

Each of the stars is in rapid movement, the star Arcturus, for instance, moves through space at the rate of 250 miles a second, but their distances are so enormous that their lateral movements are inappreciable to man in his lifetime. Thus the relative position of the constellations has not appreciably altered in the history of man, consequently the stars are considered as fixed in the sky.

The stars are all very much more distant than the sun. Their distances are impossible to reckon in miles, and can only be understood in the measure of light years, that is, the number of years that light travelling at the rate of 186,000 miles a second takes to travel from the star to the earth. While the light from the sun takes eight minutes to reach us, the light from Arcturus takes 100 years to reach the earth.

The planets which revolve with the earth round the sun change their positions rapidly with relation to the fixed stars and therefore are of no use for night marching. Planets can always be distinguished from stars in that they are generally larger and brighter and do not twinkle.

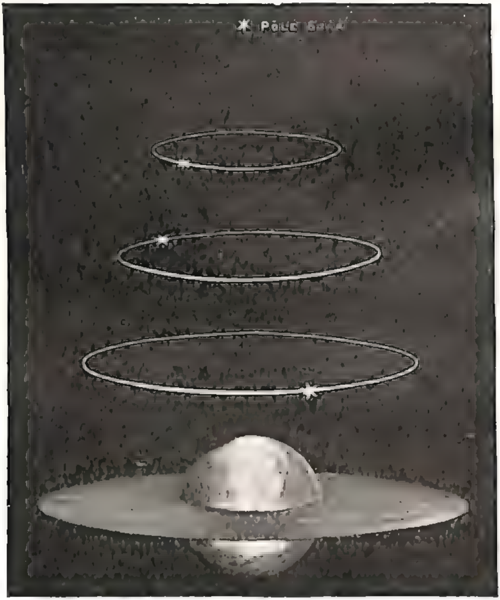


FIG. 23.

To understand the apparent motions of the stars at all different standpoints on the earth, is half the battle in knowing how to use stars for finding the way.

Suppose a man were standing at the North Pole as in Figure 23. Then he would find himself on the axis of rotation of the earth; and the stars would appear to revolve in circles

round his head. Vertically above he would see Polaris, the Pole or North Star, which would appear stationary always vertically above him. The Pole Star is practically on the prolongation of the axis of the earth to the North; and to the South the Southern Cross is above the South Pole.

Supposing a man were standing at the equator, then the stars would appear to rise in the East, pass in vertical circles overhead and set again in the West. The point in the heavens vertically overhead (at any position on the earth) is called the zenith; and the plane passing through the celestial

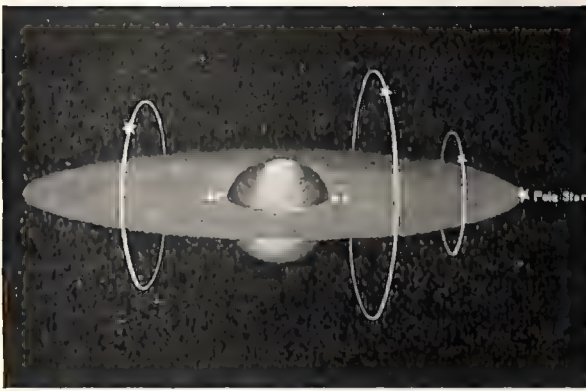


FIG. 24.

poles and the zenith is called the plane of the merdian. Thus a man standing at the equator would see the stars rise on the Eastern horizon; ascend in the heavens till they crossed the meridian; and then descend and set on the Western horizon.

Supposing the man were standing at some place between the Pole and the equator, such as at any place in England, then the apparent motion of the stars would be as in Figure 25. The stars would be at their greatest height in the heavens as they crossed the meridian; and then they would descend and set on the Western horizon.

PICKING UP THE POINTS OF THE COMPASS FROM THE HEAVENS

The understanding of the apparent motions of the stars can now be used for picking up the points of the compass and using the heavens as a compass.

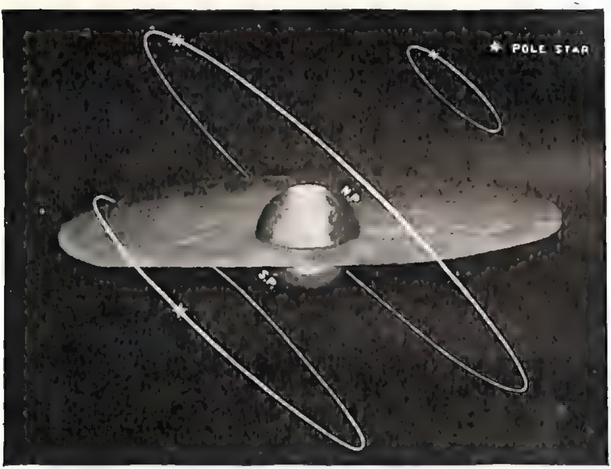


FIG. 25.

FINDING THE NORTH

True North is shown by the Pole Star (always within 2° of True North). The Pole Star is indicated by the Great Bear and its pointers; and once these have been found and learnt they can be easily recognised again at any time. If the Pole Star be watched during the night the Great Bear will be seen to rotate round it and Figure 26 shows four successive positions of the Bear for successive intervals of six hours. The Great Bear, sometimes called the Plough

or Charles's Wain, is composed of seven large stars; and it is important to study and recognise this constellation because upon it and upon the Pole Star the rules (as given later) are based for finding the positions of all the other stars used in night marching.

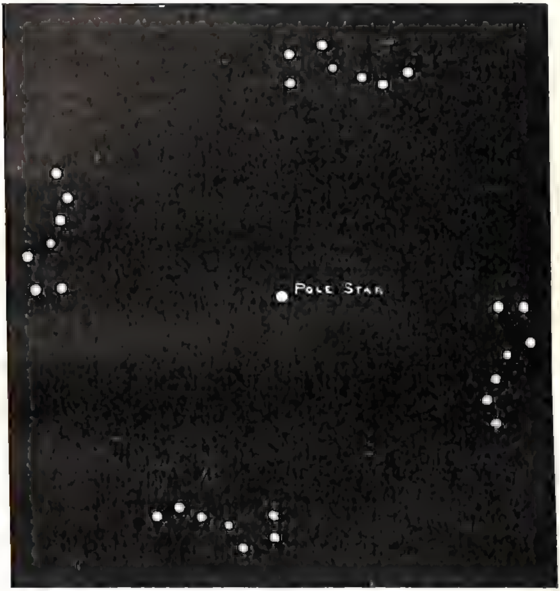


Fig. 26.

To find the North when the Pole Star is obscured, the following rules may be applied:—

(1) Take a point in line with the pointers of the Great Bear five times the distance the pointers are apart.

(2) A point half way between the pointers and Cassiopeia, or half way between Vega and Capella is approximately due North.

(3) When the pointers are vertically above one another they are due North.

(4) When the Great Bear is below the horizon, draw a line from Andromeda to Cassiopeia and produce it beyond the latter the same distance these two stars are apart.

TO FIND SOUTH, EAST AND WEST

Stand with the arms outstretched at 180° and point one hand at the Pole Star. The other hand will then point due South, and a suitable star low on the horizon or an object on the ground can be taken to indicate the South Point.

To find the East and West hold the arms at 90° and align one hand on the Pole Star and the other will give East or West.

If one cannot see the Pole Star or any other stars near it, then one can still pick up the points of the compass by lying on one's back on the ground and watching the direction of the rotation of the stars for 10 minutes or so. The method will be apparent by reference to Figure 25.

MARCHING BY THE NORTH STAR

This method affords a simple and accurate means of carrying out a rapid night march over long distances over open country.

The true bearings and distances in paces or in time are taken from the map and a chart of them made as in Figure 27 by means of a protractor.

The central black line on the paper represents the meridian, North and South. To start the march the paper is held flat in the hand and the meridian "set" to the North Star. (This can be facilitated by prolonging the line by means of a walking stick.) The first bearing then indicates the first direction for the march; and the walking stick can again be used to prolong the line and pick up another star or object on the ground as a reference object. After the distance on the first bearing is completed the paper is set again, and the new direction obtained for the second bearing, and so on.

It should be noted as for compass marching that for all star marches distances are best reckoned in paces or in time, and for this purpose either a pace or a time scale should be prepared for the map. It will be very much more convenient

to march on such a data as 250° 15′ of time than on data such as 250° 1,200 yards. If a paceometer is available, pacing generally gives more accurate results than timing.

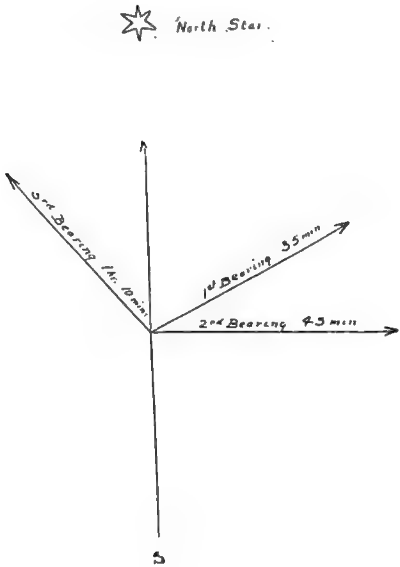


FIG. 27.

USING STARS AS REFERENCE OBJECTS FOR A COMPASS MARCH

Combination star and compass marching is the most accurate method of night marching. The compass gives the direction. The stars are used as reference objects; and by reason of their distance they give a better alignment for a bearing than reference objects on the ground difficult to see in the dark.

The only disadvantage of using the stars in this way is that they are constantly changing their bearings. The higher

a star is in the heavens the quicker it changes its bearing, so therefore a good rule is to use only stars low on the horizon. Stars up to 30° in altitude above the horizon will not alter their bearings more than 5° in 20 minutes.

MARCHING ON PREVIOUSLY CALCULATED STAR BEARINGS

This third method of star marching necessitates a knowledge of the names of the stars and an ability to recognise them in the sky. There are about 20 stars of first and second-class magnitude suitable for marching by, although, of course, they cannot all be seen at the same time.

The stars and constellations can easily be learnt by studying them with the aid of a Philips Planisphere or any star atlas.

Colonel Tilney's Tables give the bearings of all different stars for different hours of the night and different months of the year.

Supposing the data for the march were—

52° 1 hour.
125° 45 minutes, etc.

The tables are consulted for the particular month of the year and the hour of starting the march and a star is selected that gives a bearing of 52° or as near as possible. Suppose the tables gave Vega as 45°, then the march would be started using Vega as reference object but keeping 7° to the right of it. After half-an-hour or so the bearing is checked. Vega might have changed to 40°, then the march would be continued, keeping 12° to the right of Vega.

After one hour's march the direction is to be changed to 125°. The tables are consulted again and a new star selected which gives the required bearing (or as near to it as possible) for that particular hour of the night.

It should be noted, as previously mentioned, that stars of high altitude change their bearings rapidly, and therefore if used their bearings should be checked frequently.

The star bearing tables suffer from a disadvantage of not providing quite enough stars. The ideal would be to have a star for every 20° of bearing, because frequently in the tables gaps of as much as 100° exist without any direction star being given. There is no reason why the tables should not be considerably amplified.

Lateral distances in degrees can be measured by a notched stick held horizontally at arm's length from the eye. The

notches should be at every 5°, and they can be cut experimentally by means of a protractor.

Another method of measuring lateral distances (in degrees) is by the span of the knuckles and fingers when the arm is held horizontally at full extent, palm downwards. The following figures are for an average length of arm and size of hand—

The first two knuckles span 3°.
The first three knuckles span 5°.
The four knuckles span 8°.

The span of the hand with all the fingers splayed wide open is 20° from the tip of the thumb to the tip of the little finger.

Learning the Stars

NOTE.—Stars twinkle. Planets do not. Distinguish stars by their distinctive colours.

1. First of all find the Great Bear and learn the stars round the Great Bear and Pole Star. Then from these all the other stars can be found by the rough rules as below.

2. POLARIS.—The Pole Star (always within 2° of True North). Indicated by the pointers of the Great Bear.

3. CASSIOPEIA.—A constellation of five stars looking like a large "W" on opposite side of Pole Star and same distance from it as the Great Bear.

4. ANDROMEDA.—A line Pole Star to Cassiopeia and same distance on gives Andromeda and the Square of Pegasus.

5. FOMALHAUT.—A line from pointers of Great Bear to Pole Star and across heavens to opposite horizon gives Fomalhaut.

6. CAPELLA AND VEGA.—Take a line from pointers of Great Bear to Pole Star and turn to the right at right angles. Capella first large bright star. Vega on opposite side of Pole Star about same distance as Capella.

7. ARCTURUS.—At the tail of the Great Bear.

8. SPICA.—Produce a line from Vega, to Arcturus and this passes by Spica near the horizon in England.

9. REGULUS.—Produce a line from Pole Star through pointers of Great Bear and same distance on and it will pass close by Regulus. Constellation in which Regulus is

placed looks like a large question mark. Regulus is the largest bottom star.

10. Denebola.—Stretch a line between Arcturus and Regulus and about half way across is Denebola but a little below the line.

11. Antares.—Produce a line from Regulus to Arcturus and same distance on will go through Antares.

12. Altair.—Produce a line from tail star of Great Bear to Vega and the first big star beyond is Altair.

13. Orion Rigel.—Produce a line from Pole Star through Capella and same distance on will give the constellation Orion. Rigel is largest bottom star.

14. Aldebaran.—Large reddish star near Orion. The three central stars of the belt of Orion roughly point up to Aldebaran.

15. Sirius.—The three central stars of belt of Orion point down to Sirius, a very large bright star low on the horizon in England.

15. Castor, Pollux.—Stretch a stick from Regulus to Rigel, about half-way across is Pollux, a little above the line, Castor, a rather smaller star, is close to Pollux. Below the line about half-way across is

16. Procyon.—

Note.—It will, of course, depend upon the season whether any particular star is visible above the horizon or not.

CHAPTER 21

Finding One's Position on a Map by Resection

The process of accurately locating one's position on a large scale map by resection is one that requires great care and accuracy in order to get an accurate determination.

On some occasions it may be sufficient to fix one's position only roughly, and this can be done by setting the map and determining one's position by the relative positions on the map and actual directions on the ground of prominent features of the landscape.

However, to determine the position to a fine degree of accuracy to within 10 yards on a 1/10,000 map, there are four methods.

First Method. Resection by plotting the bearings of two or more prominent visible objects.

1. Take the compass bearings with all accuracy to two or more prominent visible objects (see Fig. 29).

. A, B, C.

Suppose these to be—

A	30°
B	120°
C	330°

2. Convert these magnetic bearings to true bearings (suppose the variation = 10° W.). These become 20°, 110°, 320°.

3. On the map plot the bearing of each point at each point. Thus, at "A" plot an angle of 20°, at "B" 110°, and "C" 320°. To do this, the protractor edge will be put on a vertical map grid line drawn through each point, and the variation between true North and the grid lines noted and allowed for.

4. Prolong each line backward till they meet. The point of intersection will be the observer's position on the map. All three lines should meet in one point if the angles have been measured accurately and plotted accurately.

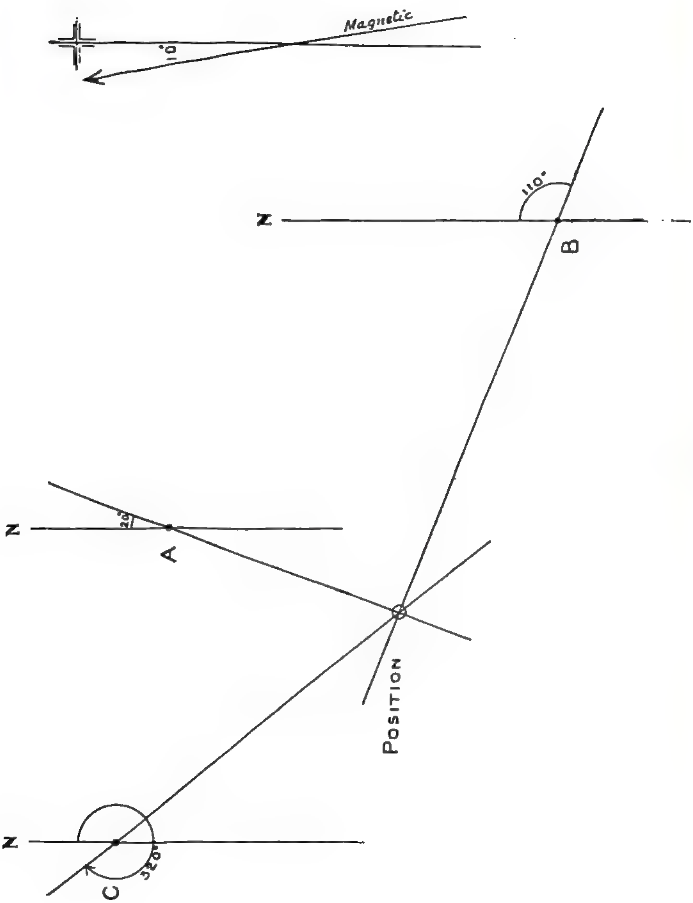


Fig. 29.

If there is a big error, repeat and check; if only a small error, take the centre of the triangle as the required position.

NOTE 1.—It is simpler to plot the actual bearings of each point at each point and prolong the line backwards, than to calculate the reverse bearings and plot those. However, the reverse bearings may sometimes be convenient to use when the point is perhaps near the edge of the map, and there would not be sufficient room to plot the actual bearing.

Reverse bearings are found.

1. If the angle is under 180° by adding 180°.
2. If the angle is over 180° by subtracting 180°.

Thus the reverse bearing of a bearing of 310° would be 130°. That is, the bearing A to B = 310°, but from B to A 130°.

NOTE 2.—A frequent error arises from plotting the magnetic bearings as measured by the compass straight, instead of converting them to true bearings. A line parallel to the magnetic meridian of the map is drawn through the point, and this line is used to plot the magnetic bearings straight. This would be quite right if the magnetic variation of the compass used were exactly the same as the magnetic variation as marked on the map. But this is seldom so. Most compasses have slight individual errors, and this causes the three lines drawn in resection to form a triangle invariably, no matter how accurately the angles are plotted.

If the magnetic bearings are going to be plotted on a magnetic meridian, instead of converting to true bearings and plotting on a true meridian, the following must be done:—

1. The observed magnetic bearings must be corrected according to the error of the compass.

2. Or the magnetic meridian of the map must be ignored and a new meridian drawn to correspond with the magnetic variation of the *compass*.

Second Method.—The Pin Method. Setting Map by compass and aligning pins on three prominent visible objects.

1. Set the map by compass as accurately as possible. Remember to make allowance for error of compass, if any. Spread the map on a board or flat surface. (See Fig. 30.)

2. Choose three prominent visible objects: A, B, and C.

Keeping the map set by compass, place a pin in representing "A" on the map, and then getting behind this pin, put in another pin about 6 inches behind, in line with the pin and the object "A" on the ground. Join these two pin holes with a line. Repeat this process for both the other objects, B and C. The three lines so drawn will intersect in one point, giving the observer's position on the map.

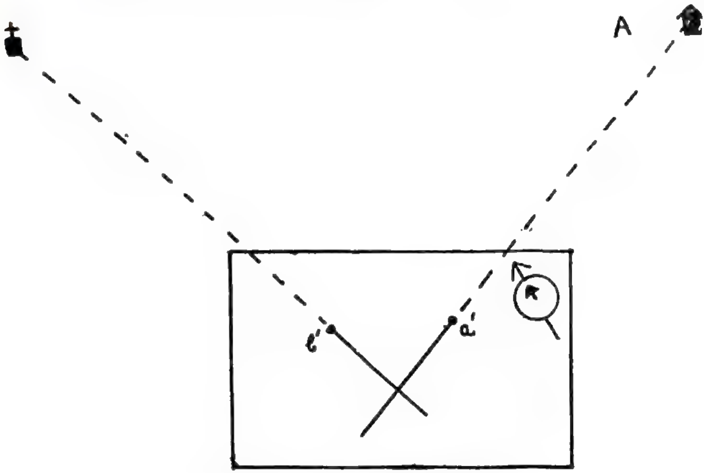


FIG. 30.

N.B.—Two objects sufficient. Third acts as check.

NOTE.—If the three lines do not meet in one point, but form a triangle of error, adopt the following method of finally fixing the spot.

1. If the observer stands *inside* the triangle on the ground formed by the three objects, his position will be *inside* the triangle of error. If he stands *outside* the triangle, his position on the map will be somewhere *outside* the triangle of error.

2. If the position is inside the triangle of error, it will be so placed that it is distant perpendicularly from each ray proportionately to the length of the rays (Fig. 31).

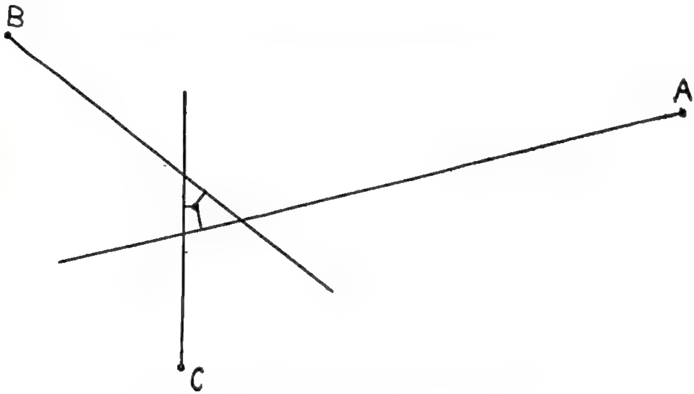


Fig. 31.—Position inside Triangle of Error.

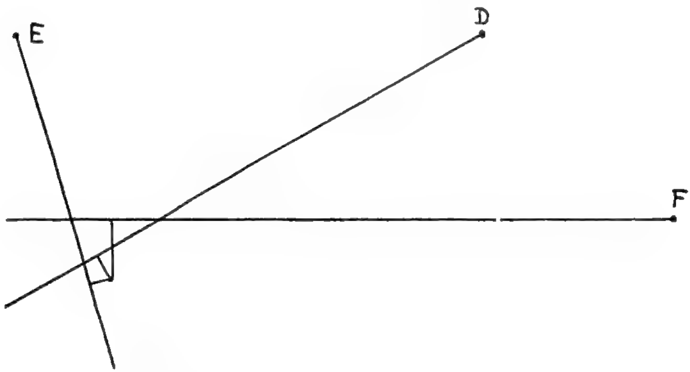


Fig. 32.—Position outside Triangle of Error.

3. If outside the triangle of error, there are only two alternative positions—on the right or on the left of *all* of the rays when facing the fixed points. Here, again, the exact spot can be determined by the same conditions as in (2) farthest from the longest ray and closest to the shortest perpendicularly (Fig. 32).

Third Method.—By shooting three rays to three objects on a sheet of transparent paper and fitting to map.

A pin is placed in anywhere about the centre of a sheet of transparent paper, and three rays are aligned and drawn to three objects on the ground. The paper is then applied to the map and twisted and adjusted so that each ray cuts its respective object on the map. When this is done the paper is pricked through at the pin hole where the three rays meet, and that gives the exact position on the map.

Fourth Method.—By plotting the compass bearing of one object and measuring the range to it by a range-finding instrument.

The bearing is plotted at the object on the map and the line produced backwards or the reverse bearing is plotted. The length of the ray is determined by the range measured on the map scale.

This is a useful method when only one object can be seen and a range-finding instrument is available. Steward's pocket telemeter is useful for this purpose.

Fifth Method.—By traversing to the nearest known object.

This is the only method that can be used when there are no prominent objects visible on which to take bearings, as in a wood or in a desert.

Traverse to the nearest object on the ground whose position is identified on the map. Plot the traverse in the reverse direction by reverse bearings, from the object to the original position. (See Chapter on "Compass Traversing.")

Notes

When selecting prominent objects in the landscape to use as points for resection, the following rules should be observed.

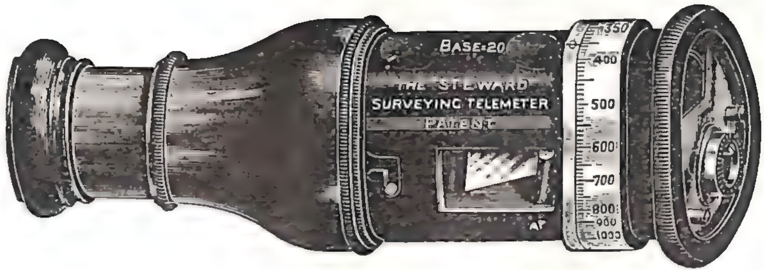
1. The objects should be close rather than distant, because when drawing the rays on the map, any slight error in their angle of direction will widen out to a larger and larger error the longer the ray becomes.

2. The angle of intersection of rays should be 90° if possible. In any case, not less than 50° or more than 130°, because when two lines meet at a very acute or very obtuse angle, any slight error in drawing them will cause a large displacement of the point of intersection, while, on the other hand, if they meet at right angles, the effect of the error is reduced to the least.

3. In the pin method (Method 2), the map should be set by compass on a magnetic meridian passing through or very close to that part of the map actually being used. The reason for this will be seen if a large map is used and the map set by compass on the meridian at the right edge. The left edge of the map can be displaced as much as an inch without making hardly any visible difference to the correct setting of the compass.

4. Resection is liable to be inaccurate if the observer's position and the reference objects are all situated on or nearly on the circumference of a circle. The best is for the observer to be at the centre and the objects on the circumference of a circle.

The rule applies only to Methods 2 and 3, not to Method 1.



Pocket Telemeter.

See Chapter 14 for description and uses.

CHAPTER 22

Locating on a Map the Position of a Distant Object

Just in the same way as a compass can be used for finding one's own position on a map, so also it can be used for fixing the position of distant objects or inaccessible objects.

This method is frequently required, and is very useful in sketching, because the sketcher is enabled thereby to fix a large number of points on his sketch without actually having to go to those points. Also, in route traversing it enables the sketcher to fix the positions of objects on either side of his route, and so adds to the utility of his sketch and saves time, as the sketcher can continue along his route without making any side journeys. Again, it is useful in adding information to an existing map.

Method.—Observe the compass bearings of the object from both ends of a base line, and plot these bearings on the map. The intersection of the rays so drawn will fix the position of the object. (See Fig. 33.)

"A" is the observer's position on the map from which he requires to fix the position of "X" seen on the ground. The compass bearing to "X" is measured; say this is 70°. The observer selects a base line, "A B," "B" being an object whose position he identifies on the map; he walks to "B" and from there measures the compass bearing to "X." Say this is 50°. These bearings are converted for convenience in plotting to true bearings. Suppose the compass variation is 10° W. These become 60° at "A" and 40° at "B." These bearings are respectively plotted at "A" and "B" on true N. and S. lines. The intersection of the rays so drawn fixes the position of "X."

Notes.—1. A base should be selected so as to give as wide an angle of intersection as possible. Frequently a narrow one is unavoidable; in this case great care should be taken in plotting the bearings.

2. The position of "X" could also be fixed as in the pin method of resection (which see). The map could be set by compass and rays drawn out from either end of the base line "A B" by aligning pins. The intersection of the rays so drawn would fix "X."

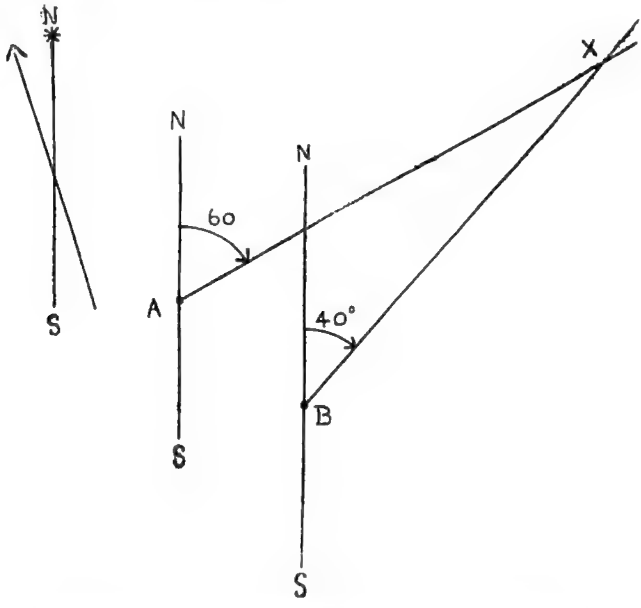


Fig. 33.—Fixing the position of a distant object (x).

Again, if some range-finding instrument were handy, then one single ray "A X" would suffice. The range to "X" would determine the length of the ray by the scale of the map. Steward's telemeter is useful for such work in sketching.

CHAPTER 23

Measuring Horizontal Angles on the Ground with a Compass

The compass measures magnetic bearings. That is, angles between objects and the magnetic meridian.

An observer standing at A (see Fig. 34) wishes to measure the angle B A C, the angle between two objects B and C.

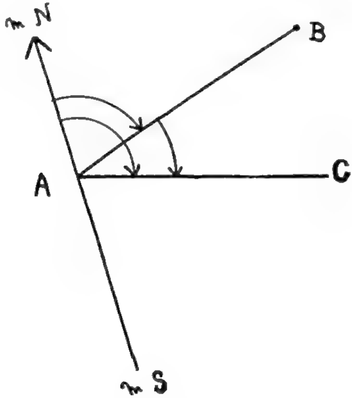


FIG. 34.

He reads the magnetic bearings of both B and C, and subtracts one from the other to get the angle berween them. This can be understood from the diagram. M N and M S is the magnetic meridian.

It is always best to do the problem by making a rough diagram as in converting true to magnetic bearings, and *vice versa*, because the case is different if the meridian lies between the two points. Here the difference between the two bearings must be subtracted from 360° to find the required angle. The drawing of a diagram makes the answer apparent.

CHAPTER 24

Finding the Range to an Inaccessible Object by Compass

It is required to find the range from a position "A" to an object "C" (see Fig. 35). Select a base A B. Read the angle C, A, B by compass as in the above method. Pace the number of yards to B, and measure the angle C, B, A. Take a piece of paper, and plot this triangle with a protractor to any convenient scale. Read the length of A C in terms of the scale used.

The width of a river can also be found by this method. Or use Steward's pocket telemeter (see Chapter 14).

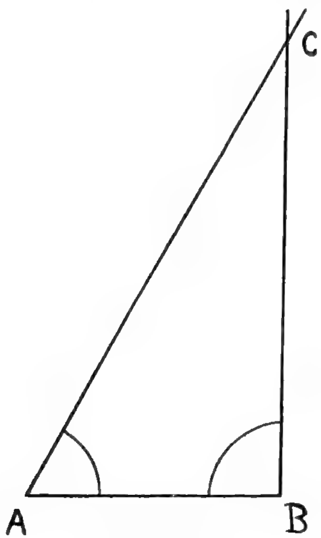


Fig. 35.

CHAPTER 25

Traversing with the Prismatic Compass

The process of traversing with a prismatic compass is used for sketching roads, rivers, etc., or a length of country covered in a march. Traversing will be used also for adding information to a map.

The method will best be understood by reference to Fig. 36.

A sketcher wishes to traverse the route from A to F, and follows the line A, B, C, D, E, F. To start, he takes the compass bearing to B, the edge of the wood, and also a bearing to the farmhouse G, an object he sees and wishes to include in his sketch. He notes these bearings in a pocket-book or "field book."

The distance A to B is paced in yards and recorded A and B. A bearing to G is taken. Here the direction of the route is changed, so the new bearing is measured B to C, and so on till F is reached. On the way, bearings are taken to different objects to the left or right of the route in order to fix their positions in the sketch.

From the completed field book, the sketch can afterwards be prepared, by plotting the bearings from the magnetic or true North and South line marked on the sketch paper, and the distances are drawn to scale.

By plotting the bearings of the farmhouse G at A and B, the intersection of the rays so drawn will fix the position of G on the sketch. Similarly, the position of the hilltop H is fixed, and the N.W. and N.E. corners of the wood.

This method of plotting the sketch from a field book is the most accurate method of traversing, but it is a little slow. Another method can be employed of sketching on the paper at the same time as the march is taking place. The sketch is "set" at each point, A, B, C, D, E, by compass by the magnetic N. and S. line previously drawn on the paper. Then the rays such as A, G and A, B are drawn by placing a pin in at A on the sketch, and aligning a ruler on to the objects G and A and drawing the rays to them. The distances are drawn to scale as in the previous method.

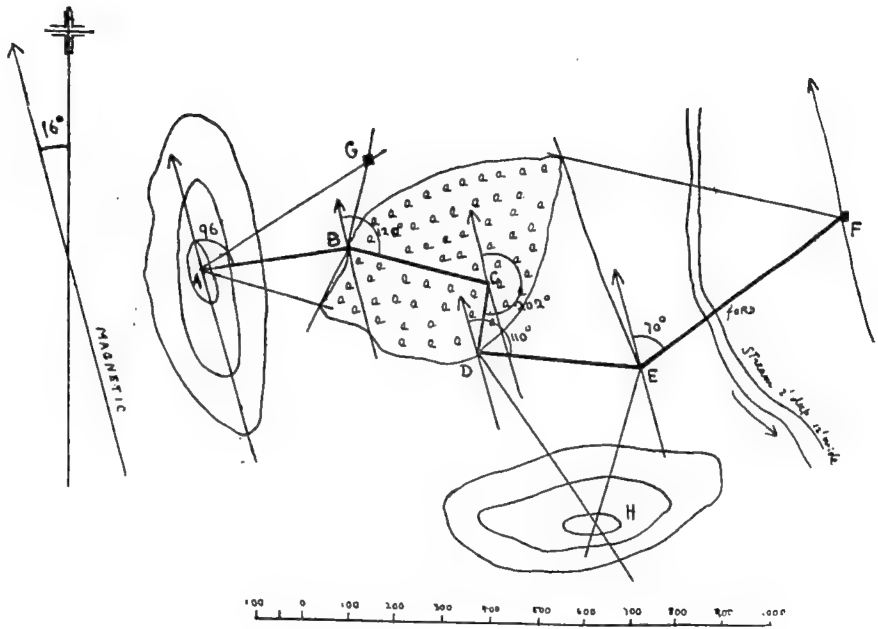


FIG. 36.—A Compass Traverse.

The accuracy of a compass traverse can be improved by taking forward and backward bearings to distant points that will be covered during the march, if they can be seen. These bearings afford a check to the ordinary rays as the traverse reaches these particular points.

Supposing the point F could have been seen from A, A being on high ground. A forward bearing to F could have been taken, and this forward bearing would serve as a check to the accuracy of the traverse when the point F was finally reached. Or, again, the points A and F might perhaps have been taken off a map, and the traverse employed to add information to the map concerning the intervening ground. If, when the traverse is plotted, the position of the last point is found to be out, the traverse must be adjusted. This can conveniently be done by tracing the traverse on transparent paper. The paper being hinged at A by a pin is shifted so that the error is corrected. The points on the traverse can then be pricked through on to the sketch, and thus the error is evenly distributed and adjusted.

Traversing will be found a useful method of finding one's position on a map. Supposing resection to be impossible through lack of reference objects to take bearings on, a compass traverse can be made to a neighbouring object whose position is identified on the map and the traverse plotted in the reverse direction by back bearings from the object to the original position.

SPECIMEN OF FIELD BOOK OF PRISMATIC COMPASS TRAVERSE

N.E. corner of wood, 280°.	350	F.	70°	—
——	180	Ford over stream 2 ft. deep 12 ft. wide, direction N. by E.—S. by W.	—	—
N.E. corner of wood, 352°.	350	E.	110°	Hill H., 212°
——	150	D, edge of wood.	202°	Hill H., 160°
Farmhouse, G., 26°	300	C.	120°	—
——	325	B, edge of wood.	96°	S.W. corner of wood, 220°
Farm house, G., 72°	—	A.	—	S.W. corner of wood, 120°
Objects on left of route.	Distance yards.	Stations	Magnetic bearings.	Objects on right of route.

CHAPTER 26

Testing a Compass

A compass is a delicate instrument, and makers' faults should be watched for. It is a good plan to test one's compass frequently for different faults that may arise through damage and accidents.

1. Test the magnetic variation and determine any error of the compass. The method has already been seen, and it is as well to remember that a compass error is of no particular disadvantage as long as that error is known and allowed for. It is a good plan to test the variation of the compass frequently in different localities in order to discover the presence, if any, of local magnetic attractions due to iron ore in the ground and other factors which may completely upset the compass.

NOTE.—The principal disadvantage of a compass error is the inconvenience when using the compass to set a map on occasions when extreme accuracy is needed, as in resection.

2. Test the strength of the magnetic needle to see if it is weak, and perhaps losing magnetism. This will be shown by sluggishness in the dial swinging, and giving a slightly different reading each time an observation is made. Needles can be re-magnetised or new ones fitted.

3. See the dial swings freely on its needle, and is not bent or damaged. See that the locking clamp and check spring work satisfactorily.

4. See that the prism is not loose or bent in prismatic compasses.

5. See that the sighting vane is in the same line as the line of the nick in the top of the cover and the nick at the end of the brass ring. Place the compass on a piece of paper flat, and place pins in at these two nicks and in the two pin holes at each end of the sighting vane. Both sets of pins should be in line. An error easily occurs here by the brass ring getting bent. This applies chiefly to the Military Mark VIII Compass.

6. Test the accuracy of the night marching device. Take a bearing to an object, then set the night marching index or lubber line to that bearing, and see if the compass cover gives the correct direction for marching. It should point straight to the object.

7. Test the luminosity of the luminous points. If they are in luminous paint, it is a good plan to get them touched with radium paint, which is permanently radio-active.

8. Test the accuracy of the dial graduations. Measure the angles to various distant landmarks with the compass and check these by careful measurements with a protractor on an accurate large scale map. Make tests for various angles round the full circle.

WARNING.—Do not attempt to remove the cover nor refill the oil of a liquid compass.

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